AN ANALYSIS OF MARINE CORPS ENLISTED PERSONNEL COHORT DATA

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THESIS

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ABSTRACT

Data from Marine Corps enlisted cohorts are analyzed to give insight into personnel flow through the enlisted Marine Corps system. In this paper, a cohort is a group of enlisted men who enlist in a given calendar month for a given length of obligated service. Stationarity assumptions between cohorts from different months are investigated. A major portion of the analysis is devoted to the extrapolation of the incomplete data on four-year enlistees based on the data from two-year and three-year enlistees. A prediction is made of enlisted strength for 1 January 1972 using the results of the analysis in a cohort prediction model. This is compared with the actual strength as of 1 January 1972. Refinements and associated models are suggested for further study.

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I. THE MODEL

In this section, we formulate a model for predicting the total strength of future Marine Corps enlisted personnel. This model is based on "cohorts" of Marines (see below) and is similar to models discussed by McAfee [1] and Marshall [2].

Each Marine initially enlists in the Marine Corps for a fixed length of obligated service and begins recruit training during some month of some year along with many of his contemporaries. A group which begins recruit training in a given month and is obligated for a given length of service is called, in this paper, a cohort. If adequate records had been kept on each cohort that was initiated over the past forty years, then one could simply add up the members of each cohort that remain on active duty as enlisted men and thus determine the enlisted strength. Records have not been kept in this form, however, and the task of reconstructing them would be monumental.

Since 1966 records have been kept in cohort form. Thus, the use of a cohort model is now possible in practice even though the data is incomplete. The current state of the art in personnel forecasting together with the lack of highly detailed lifetime data do not warrant the use of a sophisticated forecasting model. The model described here is simple and assumes stationarity of cohort behavior. This assumption is investigated in Chapter III. The model parameters are determined from historical data in Chapters III and IV.

To estimate the total enlisted strength at the first of a given month N, the following model is used:

Consider monthly cohorts of men whose initial length of obligated service is two years. Let

X_i = the initial total strength of the two-year cohort starting in month i.

$p(i,N;2)$ = fraction remaining at start of month N of a cohort starting in month i with a two-year obligation.

Then the expected total number of two-year obligors on active duty at the first of month N is

$$A = \sum_{i<N} X_i \, p(i,N;2). \qquad (1)$$

Note that we do not include the cohort that enters in month N, since predictions are being made for the first of the month.

Similarly, let

Y_i = the initial total strength of the three-year cohort starting in month i,

Z_i = the initial total strenth of the four-year cohort starting in month i, and

$p(i,N;t)$ = the fraction remaining on active duty at start of month N of a cohort starting in month i with an obligated service of t years. t = 2,3,4.

Since each enlisted Marine initially enlists for two, three or four years, the total expected number of enlisted men at the first of month N is

$$T = \sum_{i<N} X_i p(i,N;2) + \sum_{i<N} Y_i p(i,N;3) + \sum_{i<N} Z_i p(i,N;4). \qquad (2)$$

We next assume stationarity between cohorts having the same length of obligated active duty but starting in different months. That is, we assume

$$p(i,N;t) = p(N-i;t) \ , \quad t = 2,3,4 \tag{3}$$

for all i and any N. This says that for all cohorts with the same length of obligated service t, the fraction remaining on active duty k months after starting recruit training depends only on k and not on when the cohort started. Equation (2) now becomes

$$T = \sum_{i<N} X_i p(N-i;2) + \sum_{i<N} Y_i p(N-i;3) + \sum_{i<N} Z_i p(N-i;4). \tag{4}$$

In practice, the actual number of starting months included in the model would be limited to include only months when men could still be on active duty. That is, the summations in (4) would be only over i for which $p(N-i;t)$ is greater than zero.

II. THE DATA

The data used in this thesis were provided by Headquarters Marine Corps, AO1M-2. They were presented in cohort form by length of obligated active service and month of beginning recruit training. The cohorts from the six months of July through December 1967 were the most complete and were selected for the analysis.

We define a cohort member's lifetime to be the time in months from the end of his reporting month until the end of the month in which he is released from his active duty obligation or until he otherwise disassociates himself from the cohort by permanently changing his active duty status. The data provided by AO1M-2 were lifetimes consistent with this definition and thus included only first-term enlistments. Although the model could be used to predict total enlisted strength, only total first-term enlistment strength is predicted because of this restriction in the data.

Each of the six cohorts of two-year obligors is traced in monthly increments for a minimum of thirty months and the three-year cohorts for a minimum of forty months, by which time over 95 percent of the lifetimes of members in each cohort have expired. The six cohorts of four-year obligors are also traced for a minimum of forty months, by which time only about 53 percent of the lifetimes of members have expired. The data from the four-year cohorts are, therefore, incomplete and missing data must be estimated (Chapter IV).

In the original data from Headquarters Marine Corps, completed lifetimes for each month traced are divided into five separate groups as follows:

R1 - Separated altogether from the Marine Corps usually for mental, physical or disciplinary reasons.

R2 - Re-enlistment, leaves cohort by changing length of obligated service.

R3 - Released from active duty, transferred to Marine Corps Reserves.

R4 - Dropped as a deserter.

R5 - Accepted as an Officer Candidate, leaves cohort by changing status.

Table I gives an example of the cohort data for two-year obligors starting in October 1967. The complete data base is given in Appendix A.

Groups R2, R4 and R5 amount to a very small percentage of any given cohort and hence, for analysis purposes these are grouped together with R1 to form two basic categories of lifetimes:

a) Attrition - Cohort members who for various reasons do not complete their tour of active duty as originally obligated. (R1 + R2 + R4 + R5).

b) EOAS - End of Obligated Active duty Service. Members who complete their active duty obligation to the satisfaction of the Marine Corps and are transferred to the Reserves. (R3).

The term Total Data is used when referring to the combination of Attrition and EOAS, i.e., to all the members of a cohort.

TABLE I

Example of Cohort Data
Two-year obligors, starting in October 1967

Initial Strength = 2034

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	38					38	1996
2	35			1		36	1960
3	15					15	1945
4	10					10	1935
5	5					5	1930
6	10			1		11	1919
7	32				3	35	1884
8	20					20	1864
9	10					10	1854
10	22				8	30	1824
11	10					10	1814
12	13			1	1	15	1799
13	10	1				11	1788
14	10	1		1		12	1776
15	14			1		15	1761
16	12	1	5	1	1	20	1741
17	19	2	10			31	1710
18	14	2	73	1	1	91	1619
19	18		376			394	1225
20	5	1	205			211	1014
21	9	2	72	1		84	930
22	17	6	110	2		135	795
23	16	1	137			154	641
24	17	5	432			454	187
25	13		33			46	141
26	7		17			24	117
27	3		18	1		22	95
28	3		3	1		7	88
29	5		6			11	77
30	7		2			9	68
31	2		0			2	66
32	6		2			8	58
33	3		2			5	53
34	2		1			3	50
35	1		4			5	45
36	0	1	5			6	39
Total Losses	433	23	1513	12	14	1995	

III. THE ANALYSIS

A. PURPOSE

The purpose of analyzing the past lifetime distributions of enlisted cohorts is first to determine if the stationarity assumption (Chapter I) is reasonable. Secondly, the analysis yields values for the model parameters $p(k;t)$, $k < N$, $t = 2,3,4$.

B. STATIONARITY

All cohorts with the same length of obligated active duty are considered together and called a grouping. Each cohort grouping is treated separately during this first portion of the analysis. Using the Total Data (Attrition plus EOAS), the fraction of a cohort whose lifetimes exceed a given number of months (survivor function) was plotted for each cohort and mean lifetimes calculated. Thirty-month means for the two-year cohorts and forty-month means for the three and four-year cohorts are plotted in Figure 1. No significant trends are obvious and the maximum difference between any two means within a grouping is less than five percent of the aggregate mean. Since more complete data are available on two-year cohorts, the thirty-month means of the January through June 1968 cohorts were also computed and plotted. These additional values remained within five percent of the aggregate mean and indicated no obvious trends.

The values of the four-year cohorts' forty-month means are not representative of the true mean of a four year cohort because only some 53 percent of the lifetimes are represented. However, the small variation within which the values fell at this common cut-off time

and the similar shapes displayed by the three curves in Figure 1 indicate that though these estimated means are numerically low, the true means would follow these estimates and hence would show no obvious trends.

The mean lifetimes of the cohorts, therefore, appear to be constant over time within groupings. This tends to support the stationarity assumption.

Next, the aggregate survivor function of all six cohorts was calculated for each grouping. These are plotted within the envelopes formed by extreme values of their six component survivor functions. (Figure 2).

If it is assumed that all the individual members of each cohort act independently, and if S_j is the number in a cohort of size n whose lifetimes exceed j months, then under the hypothesis of stationarity S_j would be a binomially distributed random variable with parameters n and π_j, where π_j = Prob [an individual lifetime exceeds j months]. In this case the variance of S_j is $n\pi_j(1-\pi_j)$, and

$$\text{Var}\left[\frac{S_j}{n}\right] = \frac{1}{n^2}\ \text{Var}\left[S_j\right] = \frac{\pi_j(1-\pi_j)}{n} . \qquad (5)$$

The maximum value that $\pi_j(1-\pi_j)$ can be is 0.25 when $\pi_j = 0.5$ and thus

$$\text{Var}\left[\frac{S_j}{n}\right] \leq \frac{0.25}{n} .$$

The maximum variances for the three Total Data aggregate sample tail distributions (survivor functions) under the stationarity and independence hypotheses are displayed in Table II below.

Table II

Maximum Variances for Total Data Aggregate Distributions

Grouping	Sample Size (n)	Max Variance (σ^2)	2σ
2-year	11728	$.213 \times 10^{-4}$	.00923
3-year	8849	$.282 \times 10^{-4}$	.01063
4-year	21122	$.118 \times 10^{-4}$	.00688

It must be concluded that either the stationarity or independence assumption (or both) does not hold. Clearly, individual members do not act independently with regard to leaving active duty. Since all the men follow very similar career patterns during their first term and are all subject to the same perils and policies, they can be expected to act in similar ways.

The six component sample distributions of each grouping were plotted on the same graph in order to further investigate the stationarity assumption. The distributions crossed each other several times and indicated no clear trends. The distributions for the cohorts of July, September and November are plotted for each of the three groupings in Figures 3, 4 and 5 for the two-year, three-year and four-year groupings respectively. These plots also tend to support the stationarity assumption.

C. INHOMOGENEITY IN COHORTS

For further insight into the cohort behavior, the Total Data of each cohort are split into the two basic categories of Attrition and EOAS (Chapter II). The distributions of each category within each grouping are plotted and investigated for stationarity as was done on the Total Data.

With only 53 percent of the lifetimes of four-year obligors completed, it is not known what fraction of a given four-year cohort will eventually fall into each of the two categories, Attrition and EOAS. It is, therefore, necessary to determine estimates for these fractions. This is done in the following manner using the data from the aggregate distributions: Let

Z = the active duty lifetime of a four-year enlistee.

Z_1 = the active duty lifetime of a four-year enlistee given that he will fall in the EOAS category.

Z_2 = the active duty lifetime of a four-year enlistee given that he will fall in the Attrition category.

p_1 = the probability that a four-year enlistee will fall in the EOAS category.

p_2 = the probability that a four-year enlistee will fall in the Attrition category. $(1-p_1)$.

Then the following relations hold:

$$P[Z \leq z] = p_1 P[Z_1 \leq z] + p_2 P[Z_2 \leq z] , \qquad (6)$$

$$P[Z \leq z] = 1 - P[Z > z] , \qquad (7)$$

where $P[Z > z]$ are the values plotted in the lifetime tail distribution (Figure 2, four-year curve). The values p_1 and p_2 will be determined as the estimates of the desired fractions.

From the data - and subsequently from the four-year plot in Figure 7 - it can be seen that for values of $z \leq 28$ the number of EOAS losses is negligible. Therefore, we take $P[Z_1 \leq 28] = 0$. For $z = 28$, equation (6) reduces to

$$P[Z \leq 28] = p_2 \; P[Z_2 \leq 28] . \qquad (8)$$

From the data, or from Figure 2 (four-year aggregate curves), the left-hand side of (8) is 0.215. The Attrition probability, $P[Z_2 \leq 28]$, now needs to be determined so that p_2 can be estimated.

It is noted that the aggregate Attrition distributions for the two-year and three-year groupings (Figure 6) are remarkably linear out to their original obligated service of 24 and 36 months respectively. It is reasonable to believe, therefore, that the four-year aggregate Attrition distribution will follow a similar linear function. From the values of the two-year and three-year distributions at 24 and 36 months respectively, it is hypothesized that the four-year aggregate Attrition distribution will be approximately linear from its beginning value of 1.0 at zero months to a value of 0.03 at 48 months.

Using this linear approximation, the value of $P[Z_2 \leq 28]$ is 0.566. Hence, from equation (8),

$$p_2 = \frac{P[Z \leq 28]}{P[Z_2 \leq 28]} = \frac{0.215}{0.566} = 0.380 \ . \qquad (9)$$

With a total four-year aggregate sample size of 21,122 Marines, it follows that 8032 Marines will be in the Attrition category and 13,090 will be in the EOAS category.

Based on a sample size of 8032, the forty-month data produced another remarkably linear Attrition distribution (Figure 6, four-year curve) as hypothesized. Note that a change in the sample size affects only the slope of this curve and not its linearity. The four-year EOAS distribution using the sample size of 13,090 is plotted in Figure 7 (four-year curve).

The value of $p_2 = 0.380$ is also used to determine the expected sample sizes of the two basic categories for the component distributions.

To investigate the Attrition and EOAS category distributions for stationarity, procedures similar to those used for the Total Data are followed. Essentially, each cohort is divided into two sub-cohorts, one for each of the two basic categories.

The tail distributions (survivor functions) were determined for each sub-cohort. The mean lifetimes calculated for these distributions are plotted for the Attrition and EOAS categories in Figures 8 and 9 respectively. The EOAS means (Figure 9) show a slight upward trend for the four-year sub-cohorts and no clear trends for the two-year and three-year sub-cohorts. The maximum difference in each grouping is again less than five percent of the aggregate mean.

The Attrition means (Figure 8), however, show a distinctive upward trend for the three-year sub-cohorts. No obvious trends are indicated in the two-year and four-year sub-cohorts, but the maximum difference in all three groupings exceeds five percent of the individual aggregate mean, and the differences within the three-year and four-year groupings exceed ten percent.

The mean lifetimes of the Attrition sub-cohorts, therefore, cannot be assumed to be constant over time within groupings, and thus do not support the stationarity assumption.

The aggregate Attrition distribution for each grouping was calculated and these are plotted within their envelopes of extreme component values (Figure 6). Under the stationarity and independence hypotheses (page 13), the maximum variances for the three Attrition aggregate sample tail distributions are as shown in Table III.

Table III

Maximum Variances for Attrition Aggregate Distributions

Grouping	Sample Size (n)	Max Variance ($\sigma^2 = \frac{.25}{n}$)	2σ
2-year	2803	$.812 \times 10^{-4}$	.0189
3-year	2610	$.958 \times 10^{-4}$	.0196
4-year	8032	$.311 \times 10^{-4}$	.0111

Similarly the EOAS aggregate distributions were calculated and are plotted within their envelopes in Figure 7. The maximum variances for the three EOAS aggregate sample tail distributions under the hypotheses of stationarity and independence are shown in Table IV.

Table IV

Maximum Variances for EOAS Aggregate Distributions

Grouping	Sample Size (n)	Max Variance (σ^2)	2σ
2-year	9167	$.273 \times 10^{-4}$	.0104
3-year	6239	$.401 \times 10^{-4}$	.0127
4-year	13090	$.191 \times 10^{-4}$	.0087

As with the maximum Total Data variances in Table II, these values are too small to plot on Figures 6 and 7. Again, it must be concluded that either the stationarity or independence assumption (or both) does not hold.

Within each category and grouping, the six component monthly sub-cohort distributions were plotted on the same graph to further

investigate the stationarity assumptions. Trends similar to those indicated by the plots of the means (Figures 8 and 9) were revealed tending to discount the stationarity assumption especially for the Attrition distributions. The sub-cohort distributions for July, September and November are plotted for each category and grouping in Figures 10 through 15.

It is therefore concluded that since the Attrition data do not appear to be stationary, we should not attempt to apply the data in category form to this model. However, for purposes of the model, it is felt that the Total Data can be considered as being stationary within groupings by length of initial obligated active duty service.

D. PARAMETER ESTIMATION

We assume, from the above analysis, that the Total Data distributions are stationary within groupings. Therefore, the Total Data aggergate distributions should give reasonably accurate estimates for the model parameters $p(k;t)$, $t = 2,3,4$ out to their plotted limits of $k = 30$, 40 and 40 months for $t = 2,3$ and 4 respectively.

Sufficient data are not available on lifetimes longer than 36 months for the two-year cohorts[1], and 40 months for the three-year and four-year cohorts. Assuming lifetimes ended at these points, or $p(k;2) = 0$, $k \geq 37$, and $p(k;3) = p(k;4) = 0$, $k \geq 41$, would lead to low estimates in our predictions. Therefore the parameters in these ranges are estimated in the following way.

---

[1]For all six two-year cohorts, data is available only to $k = 30$ months. However, for five of the six cohorts data is available to $k = 36$ and the parameters $p(k;2)$, $k = 31,\ldots,36$ are determined from this reduced sample aggregate distribution.

The distributions of the two-year aggregate data beyond 24 months and the three-year aggregate data beyond 36 months appear to have geometric tails (Figure 2). In other words, after the initial length of obligated service, the lifetimes of remaining members appear to be distributed geometrically. In the two-year case, therefore, a geometric distribution is fitted to the data from $p(24;2)$ through $p(36;2)$ and extended to provide the missing parameters $p(k;2)$, $k \geq 37$. These parameters are obtained by solving

$$p(k;2) = p(36;2)\, q_2^{k-36}, \quad k \geq 37, \tag{10}$$

where $p_2 = (1 - q_2)$ is the parameter of the fitted geometric distribution.

In the three-year case, a geometric distribution is fitted that extends the aggregate curve from $p(40;3)$ through a selected value of $p(48;3) = .018$, which is consistent with the corresponding two-year parameter $p(36;2)$. Since $p(40;3)$ is known from the data, the geometric parameter q_3 for this fit can easily be calculated from

$$p(48;3) = p(40;3)\, q_3^8 . \tag{11}$$

The remaining three-year parameters are then determined by

$$p(j;3) = p(40;3)\, q_3^{j-40}, \quad j \geq 41 \tag{12}$$

The extrapolations involved in obtaining values for $p(k;4)$, $k \geq 41$, are much more difficult and are discussed in Chapter IV.

IV. THE EXTRAPOLATION

The cohort data reports used as a basis for parameter extimation were last updated as of April 1971. At that point, the four-year cohorts selected had been traced for a minimum of 40 of their original 48 month obligations. Therefore, only about 53 percent of the members' lifetimes had expired. Due to reporting delays, processing time and the expense involved in obtaining the data in the desired cohort form, the lifetime distributions beyond 40 months are not available at the time of this study. In this chapter a method is proposed for estimating the desired parameters $p(k;4)$, $k \geq 41$.

From visual inspection of Figure 2, marked similarities can be seen between the two-year and three-year Total Data aggregate life distributions. Because the four-year life distributions appear also to be following a similar pattern, it is hypothesized that a relatively simple relationship can be found that will reasonably describe the four-year distribution at least up to 48 months based on the two-year or three-year distribution already plotted. After the obligated 48 months, a geometric tail can be added similar to that on the three-year distribution (Chapter III).

Relationships are established between two different aggregate lifetime distributions plotted on the same axes as follows:

Let X = lifetime of two-year (or three-year) enlistees

Z = lifetime of four-year enlistees

f = a one-to-one function relating X and Z

then $Z = f(X)$ with $X = f^{-1}(Z)$.

Now

$$\{Z > z\} \Leftrightarrow \{f(X) > z\} \Leftrightarrow \{X > f^{-1}(z)\}\ , \tag{13}$$

and hence

$$P[Z > z] = P[X > f^{-1}(z)]. \tag{14}$$

Now if $\bar{F}(x) = P[X > x]$, the tail distribution of X,

and $\bar{G}(z) = P[Z > z]$, the tail distribution of Z,

then equation (14) can be written as

$$\bar{G}(z) = \bar{F}(f^{-1}(z)), \tag{15}$$

or

$$\bar{G}(f(z)) = \bar{F}(z). \tag{16}$$

Values of f(z) up to 40 months are determined (for example, see Figure 16) and in each case (2 yr. vs. 4 yr. and 3 yr. vs. 4 yr.) are plotted against z (Figure 17). Since it is also known from experience and from the two-year and three-year distributions that over 90 percent of the lifetimes have expired at the end of the initial obligated time, appropriate weighting points are plotted at f(z) = 48 months.

By polynomial regression techniques, linear and quadratic functions were fitted to the plotted points (Figure 17). These methods yielded best least-squares approximations of the desired function f(z), which are listed in Table V below. Using these functions, the values of z are obtained for f(z) = 41,..., 48 months. Hence $\bar{G}(f(z))$, which is equal to $\bar{F}(z)$, can be plotted for f(z) = 41, ..., 48.

TABLE V

Polynomial Regression Results

Comparison	Degree of Regression	Functional Relationship f(z)
2 yr. vs. 4 yr.	First (Linear)	$3.65z - 37.6$
	Second	$15.45z - .29z^2 - 154.02$
3 yr. vs. 4 yr.	First (Linear)	$1.7z - 12.35$
	Second	$4.58z - .05z^2 - 53.9$

The best fit appeared to be a second-degree polynomial relating the Total Data aggregate distributions of the two-year and four-year cohorts (see Figure 18). This function extrapolates the four-year Total Data distribution out to approximately 50 months. (The sensitivity of this extrapolation is discussed in Chapter V.) A geometric tail is then fitted extending the extrapolation through $p(60;4) = .018$. The monthly values of this extrapolation curve are used as the estimates of the parameters $p(k;4)$, $k \geq 41$ in the model described in Chapter I.

V. THE PREDICTION RESULTS

A. PREDICTION

In order to predict the total enlisted strength at the start of a given month, we need to know the fractions $p(k;t)$ defined on page 8. The Data available to us for this thesis, however, are sufficient only to determine the total First-term enlisted strength. Except for the incomplete data on first re-enlistments (R4, Chapter II), information on re-enlistments and careerists is not included. Thus, in this chapter, we predict the total number of First-termers on active duty in the Marine Corps as of 1 January 1972, using the model parameters estimated in Chapters III and IV.

Headquarters Marine Corps, A01M-2, has furnished the initial total strengths X_i, Y_i and Z_i for the two-year, three-year and four-year cohorts respectively for the 60 starting months between January 1967 and December 1971.

To obtain the number of those members still on active duty as of 1 January 1972 and still in their first enlistment, we enter the given cohort strengths along with the parameter estimates $p(k;t)$, $k = 1,\ldots, 60$, $t = 2,3,4$, into the model described in Chapter I. Since cohort initial strengths are not known for $k \geq 61$, we estimate the number of First-termers remaining on active duty from those cohorts by

$$C_t \; p(60;t) \; \frac{q_t}{1-q_t} \; , \; t = 2,3,4 \; , \tag{17}$$

where C_t = the average of the initial cohort strengths over $k = 49, \ldots, 60$ for each grouping (t),

$p(60;t)$ = the fraction of a t-year cohort remaining on active duty at the end of 60 months,

$q_t = (1 - p_t)$ and p_t is the parameter of the geometric tail distribution fitted to the t-year aggregate curve.

These estimates are simply the remainder of the geometric distributions after 60 months applied to representative average cohort sizes for each grouping.

Incorporating these estimates into the model we obtain the results tabulated in Table VI.

TABLE VI

Model Prediction Results for 1 Jan. 1972

Enlistment Contract	Number on Active Duty
2 Years	34,797
3 Years	24,529
4 Years	73,864
Total First-termers	133,190

Headquarters Marine Corps also provided two other figures:

1) The total enlisted strength as of 1 January 1972 = 175,683 Marines.

2) The number of Marines serving on their second or subsequent enlistment as of 1 January 1972 = 38,753.

These figures imply that the total number of First-termers on active duty as of 1 January 1972 should be 136,930. If this number is indeed correct, then the model is predicting low by 3740 Marines or slightly over two percent of the total force. The model predicts that 75.81 percent of the total enlisted force are First-termers as compared with 77.94 percent derived from the reported figures.

B. EXTRAPOLATION SENSITIVITY

An important factor that contributes to the prediction accuracy is the extrapolation of the four-year aggregate survivor function from 40 to 48 months as described in Chapter IV. We therefore investigate the sensitivity of the prediction results to changes in the extrapolation curve. To do this, three alternative distributions are fitted from $p(40;4)$ to $p(48;4)$ as follows:

1) Linear - a straight line connection representing a constant number of losses per month,

2) Free Hand - an approximation to the distribution based on experience, intuition and a few incomplete reduced samples, and

3) Upper Bound - a horizontal straight line out to the 48th month representing no further losses until that month.

These alternatives are plotted in Figure 19 along with the extrapolation distribution from Chapter IV. New values of the parameters $p(k;4)$, $k = 41, \ldots, 47$ were determined for each alternative and their representative changes in the prediction calculated. These changes in numbers of men and in percent of total force are shown in Table VII.

TABLE VII

Extrapolation Sensitivity Results

Alternative	Prediction Change	Change in Percent of Total Force
Linear	- 1166	- 0.66
Free Hand	+ 901	+ 0.51
Upper Bound	+ 2471	+ 1.41

These results indicate that the final prediction of the model is relatively insensitive to the extrapolation techniques applied. Although having complete data for parameter estimation is still desireable, satisfactory estimates can be made using any reasonable technique of extrapolation.

VI. SUMMARY AND CONCLUSIONS

The model in this paper is simple and for computational purposes relies heavily on the assumption that cohort behavior is stationary over time. The more data that are available, of course, the easier it is to support or discount the stationarity assumption. Also, more confidence can be placed in the parameter estimates and, hence, in the prediction results as long as the stationarity assumption is assumed. It is felt that complete data on cohorts of the full twelve months of a year, each traced up to a minimum of one year past the initial length of obligated service is a minimum requirement for a useful data base with which to make good parameter estimates and strength forecasts.

The data analyzed for this model appear to be reliable with the possible exception of the deserter data (R4, Chapter II, Table I). For purposes of the Model, the deserter data are good, but they can be misleading if not handled consistently when making comparisons with figures from other sources. If in the latest update of a given cohort a deserter is still unaccounted for, then he appears in the data as an expired lifetime during the month he deserted. If in a subsequent update he is apprehended and returned to service for disciplinary action, he is re-entered into his original cohort and no evidence remains in the data that he was missing. On 1 January 1972, how many deserters were at large, not counted in the total strength figure and will yet be returned to service?

Any forecasting method involving many parameters which must be estimated is subject to random errors and problems with data definitions

and interpretations. It is felt that for a first pass prediction using incomplete data and crude extrapolation techniques, the results indicate considerable potential for this type of model.

VII. USES AND FURTHER STUDY

The ultimate use of this type of model is to predict total enlisted strength at some future date. To do this, the refined First-termers model discussed in Chapter VI would have to be combined with a similar model for Careerists based on re-enlistment data. Together, these two models would comprise a means of forecasting the total enlisted force of the Marine Corps. By knowing the desired force level at some distant time, say 1 January 1974, these models could be manipulated to yield suggested monthly inputs for the interim months.

Cohort models are not restricted to enlisted data, of course. Models for Officer cohorts such as described in McAfee [1] can also be useful in the same manner.

Major Marine Corps policy changes can have a significant effect on changing the shape of the cohort survivor functions and thereby changing the required model parameters. Effects of such policies as early outs or involuntary extensions could be analyzed through a cohort model by postulating life distributions as functions of the policy variables (fractions let out early, fraction extended, etc.).

Other possible areas for further study using cohort data similar to that analyzed for this paper include: effect of casualties due to hostile action on cohort attrition, survivor functions for draftees compared to volunteers, effects of deserters on total strength, and analysis of lifetimes by mental groupings.

Also, with more complete data, reasonable bounds on parameters for the model presented could be found, thus yielding a prediction range as well as a best estimate.

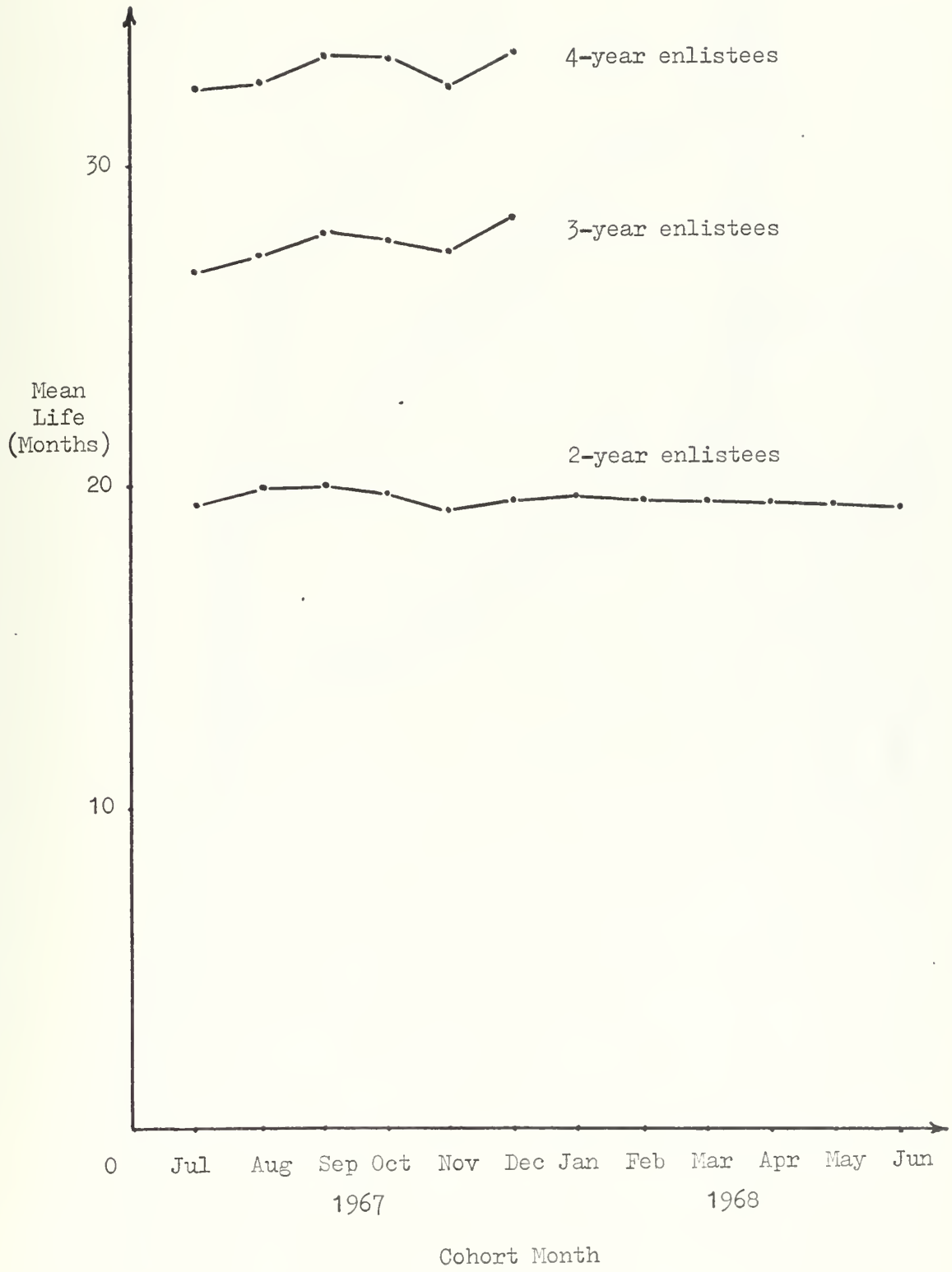

Figure 1: Total Data Mean Lifetimes

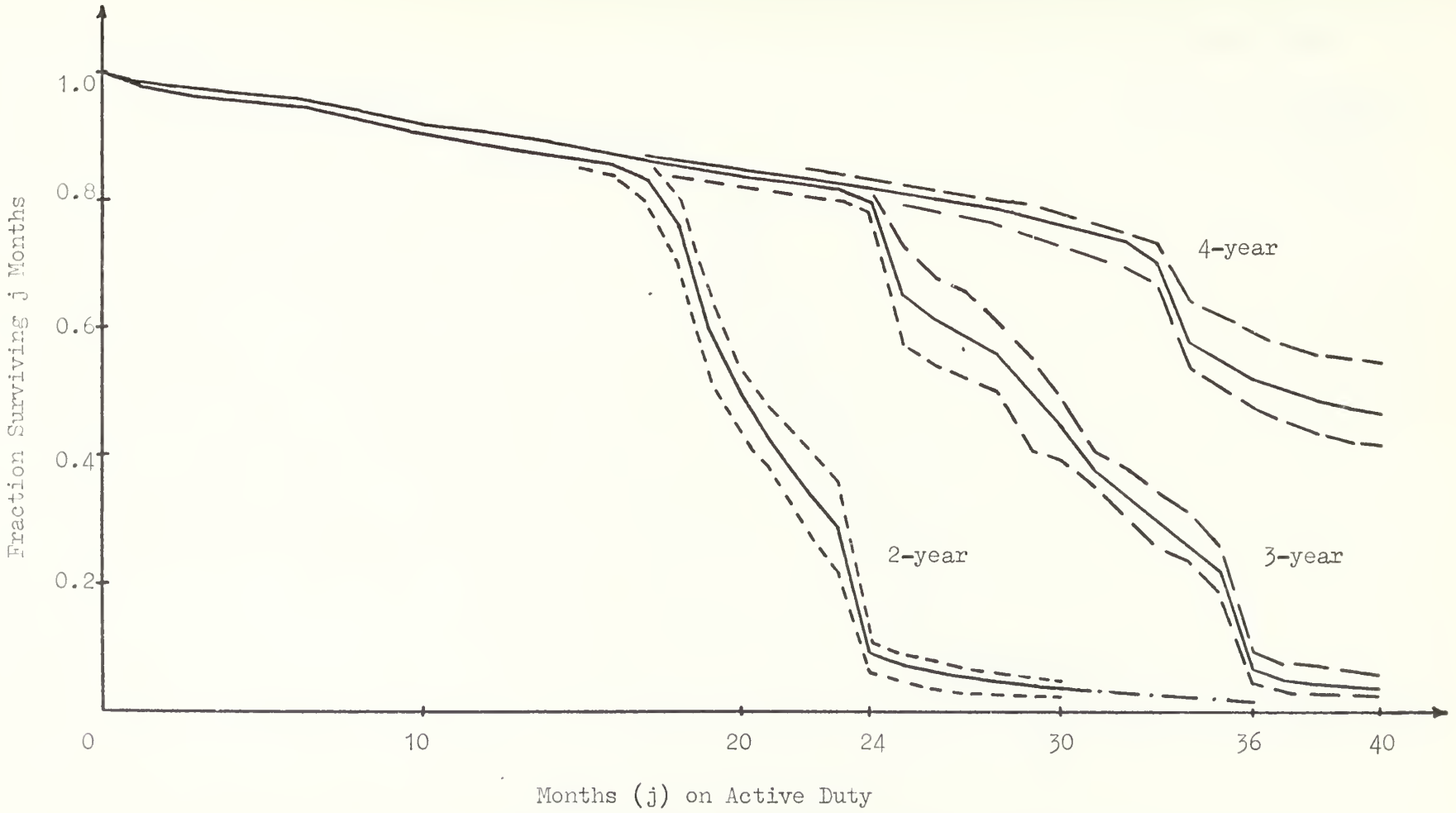

Figure 2: Total Data Aggregate Survivor Functions with Envelopes

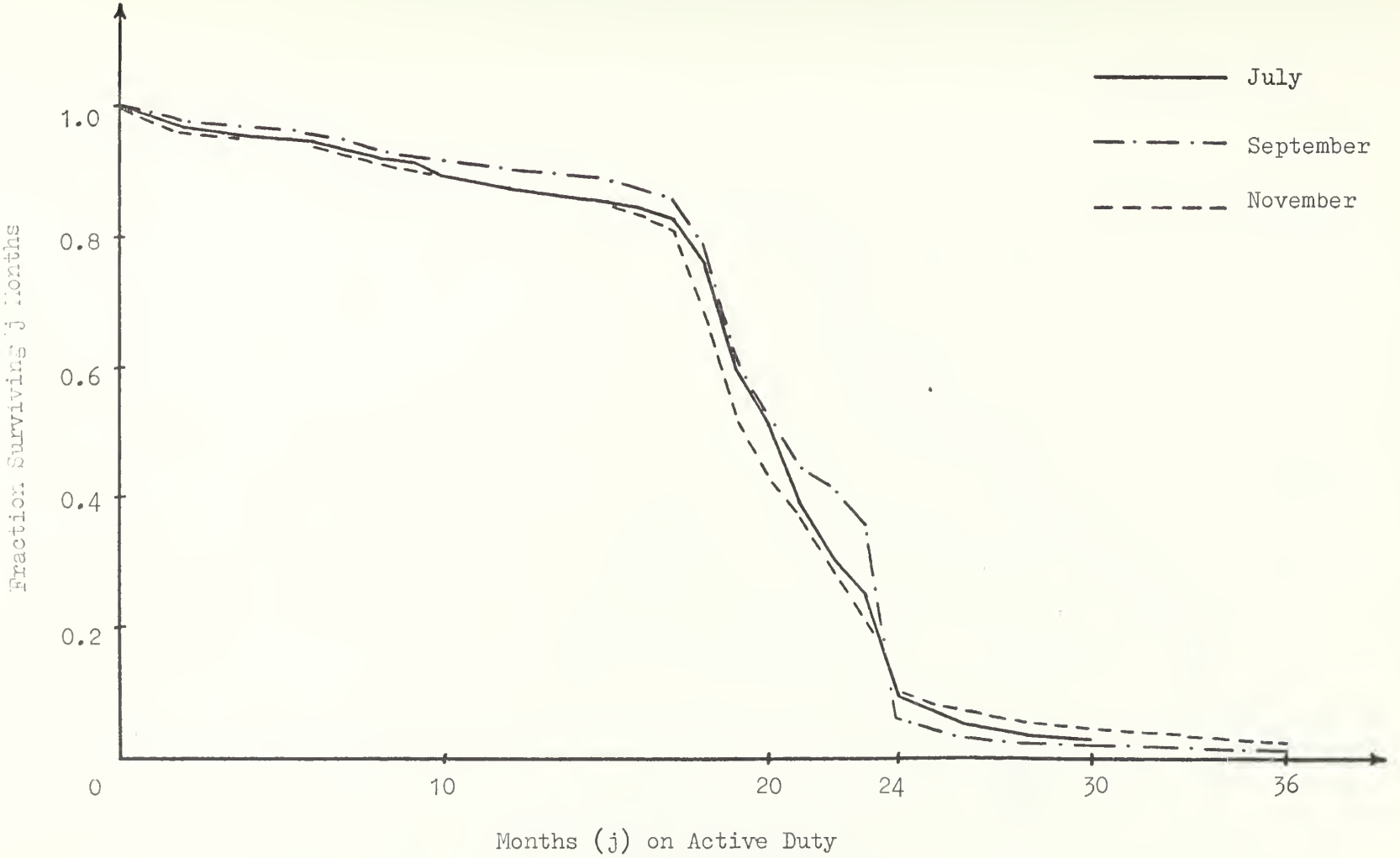

Figure 3: Distributions for Two-year Total Data Cohorts, July, September, November 1967

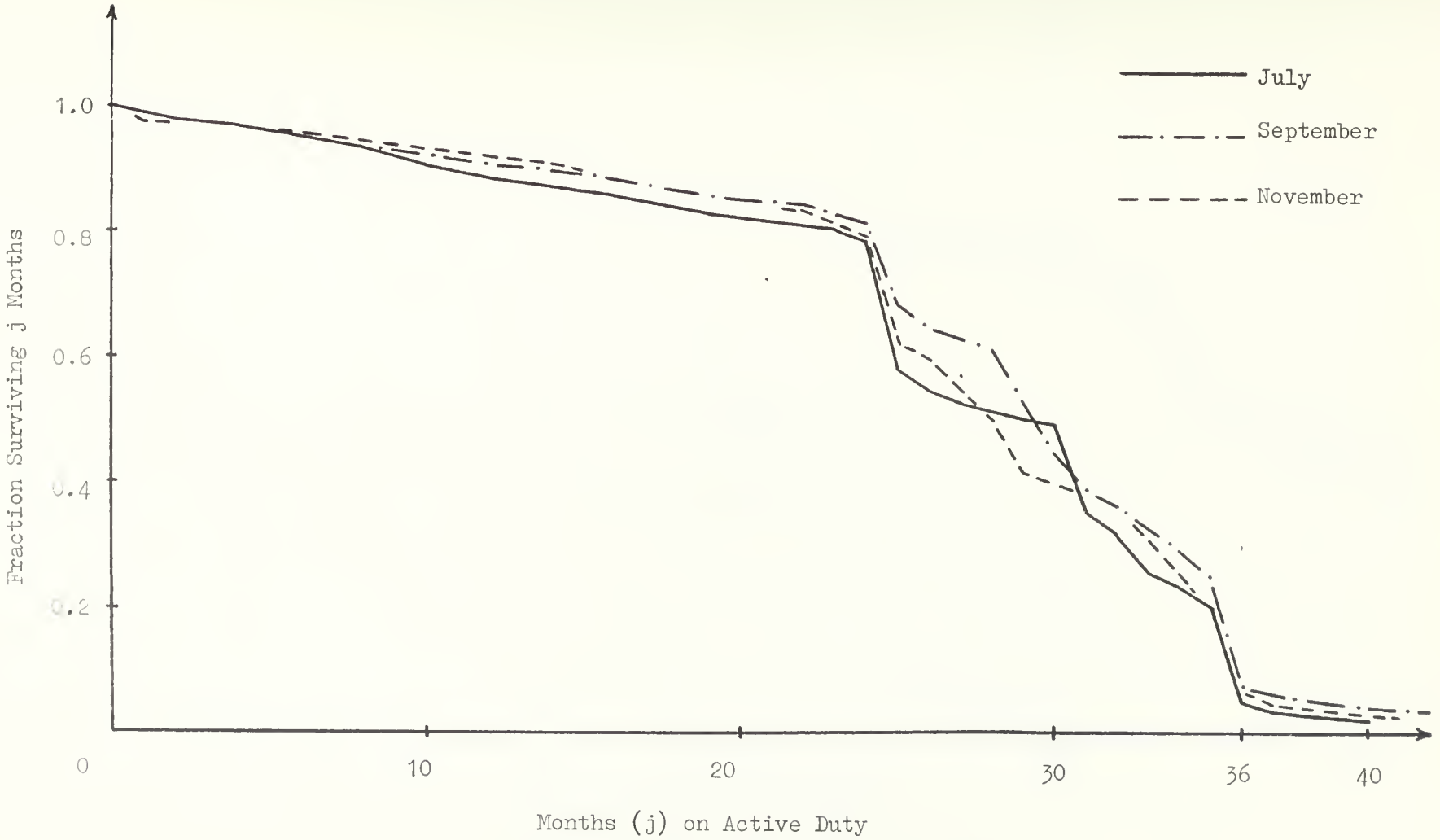

Figure 4: Distributions for Three-year Total Data Cohorts, July, September, November 1967

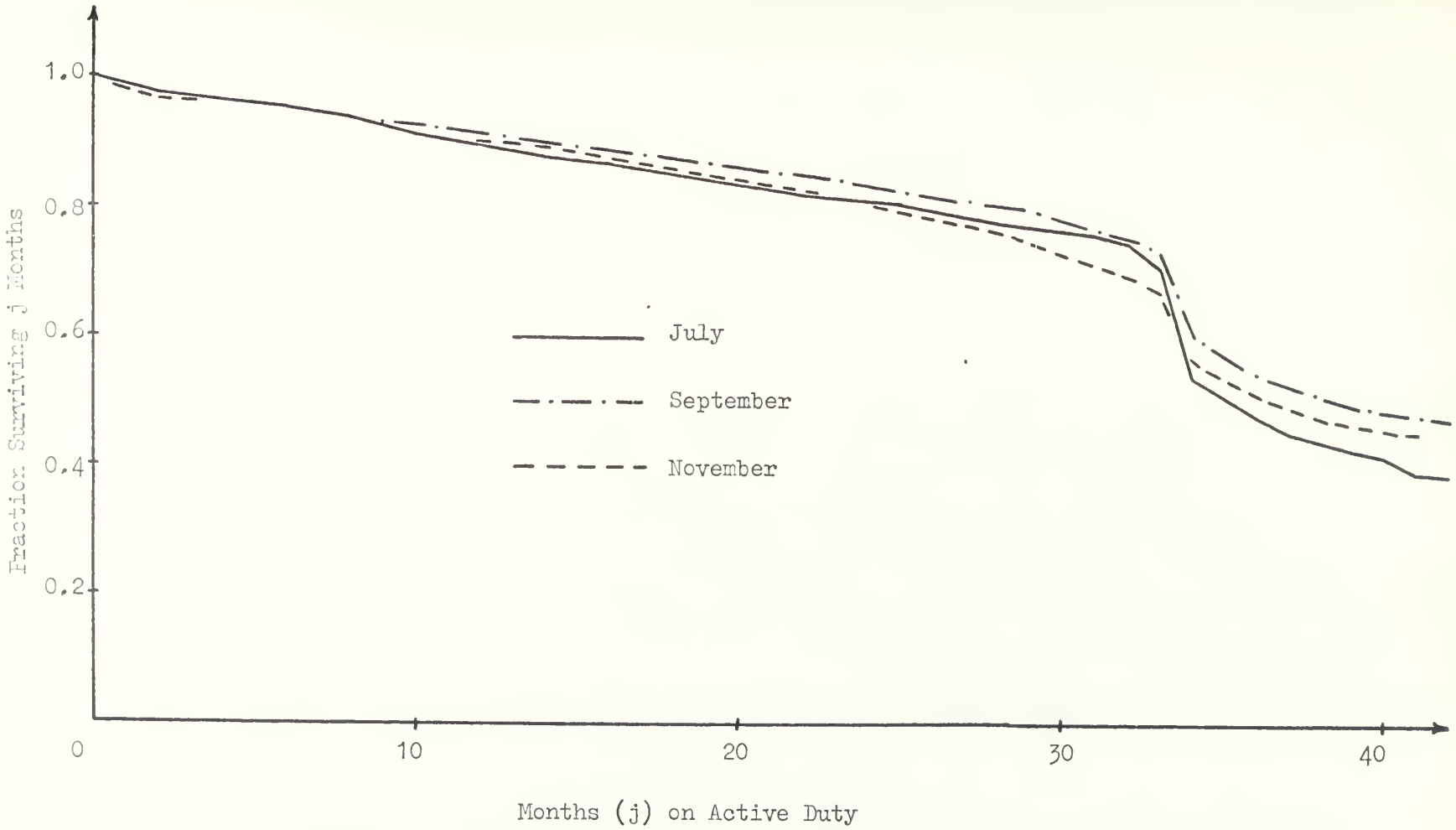

Figure 5: Distributions for Four-year Total Data Cohorts, July, September, November 1967

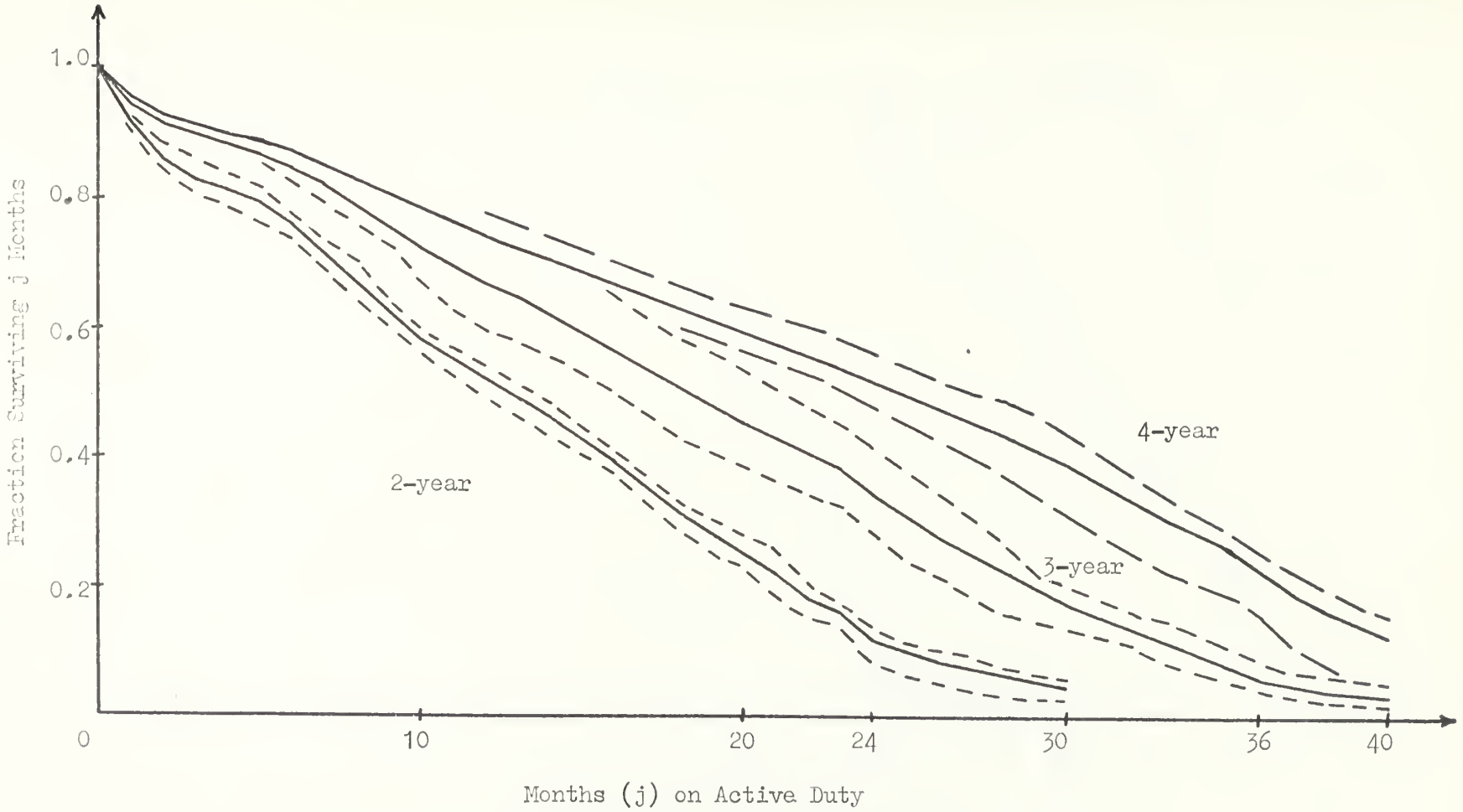

Figure 6: Aggregate Attrition Distributions with Envelopes

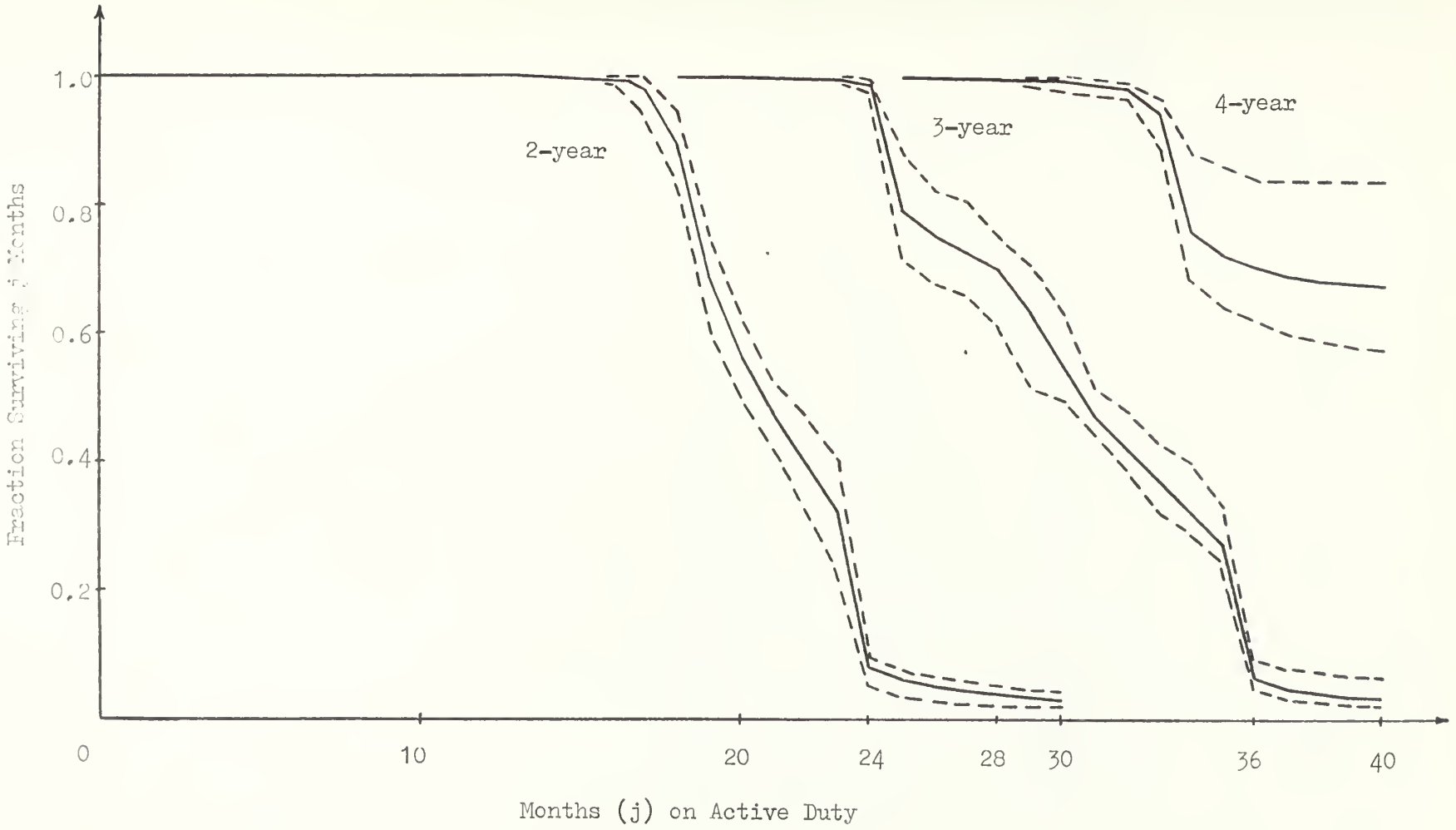

Figure 7: Aggregate EOAS Distributions with Envelopes

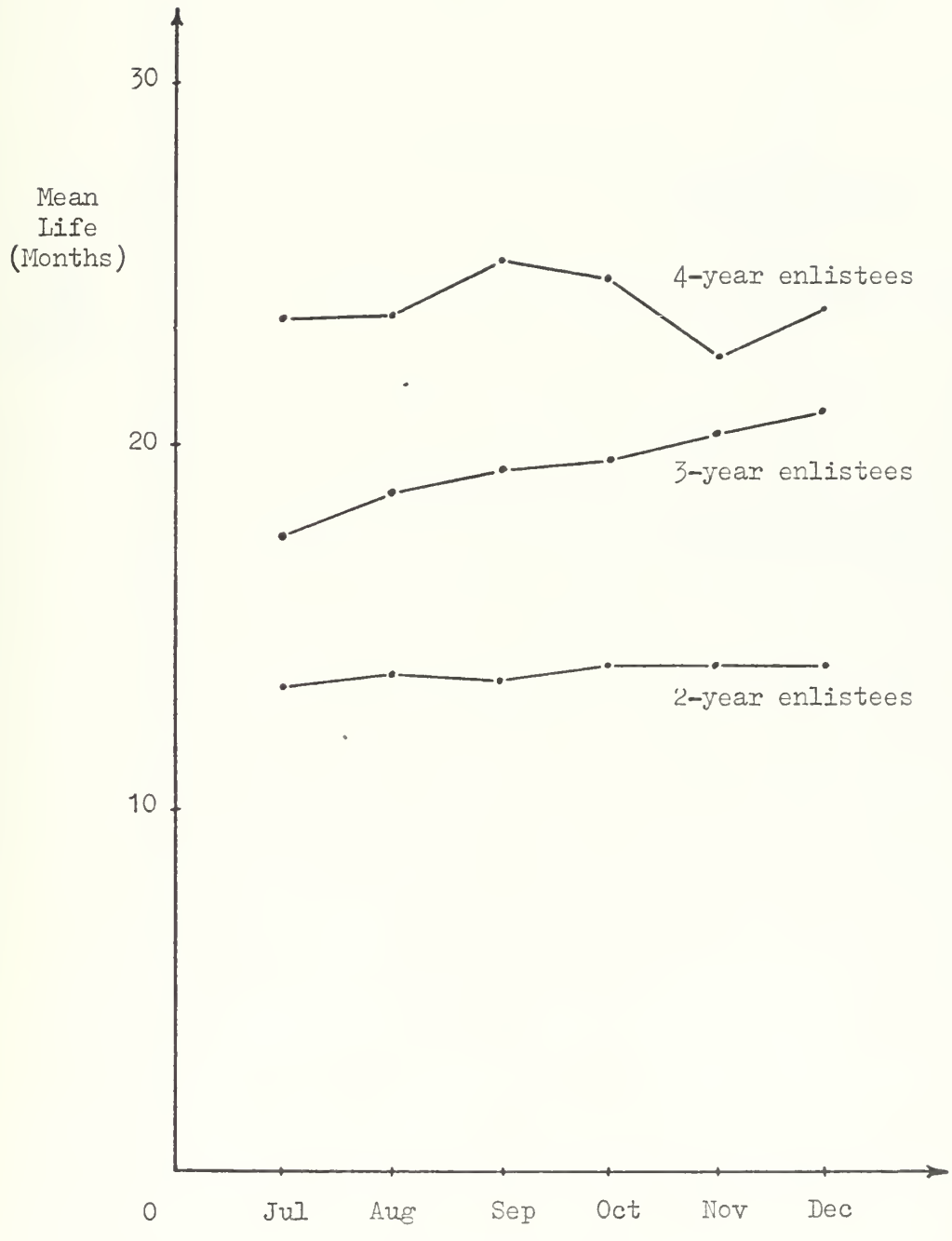

Figure 8: Attrition Mean Lifetimes

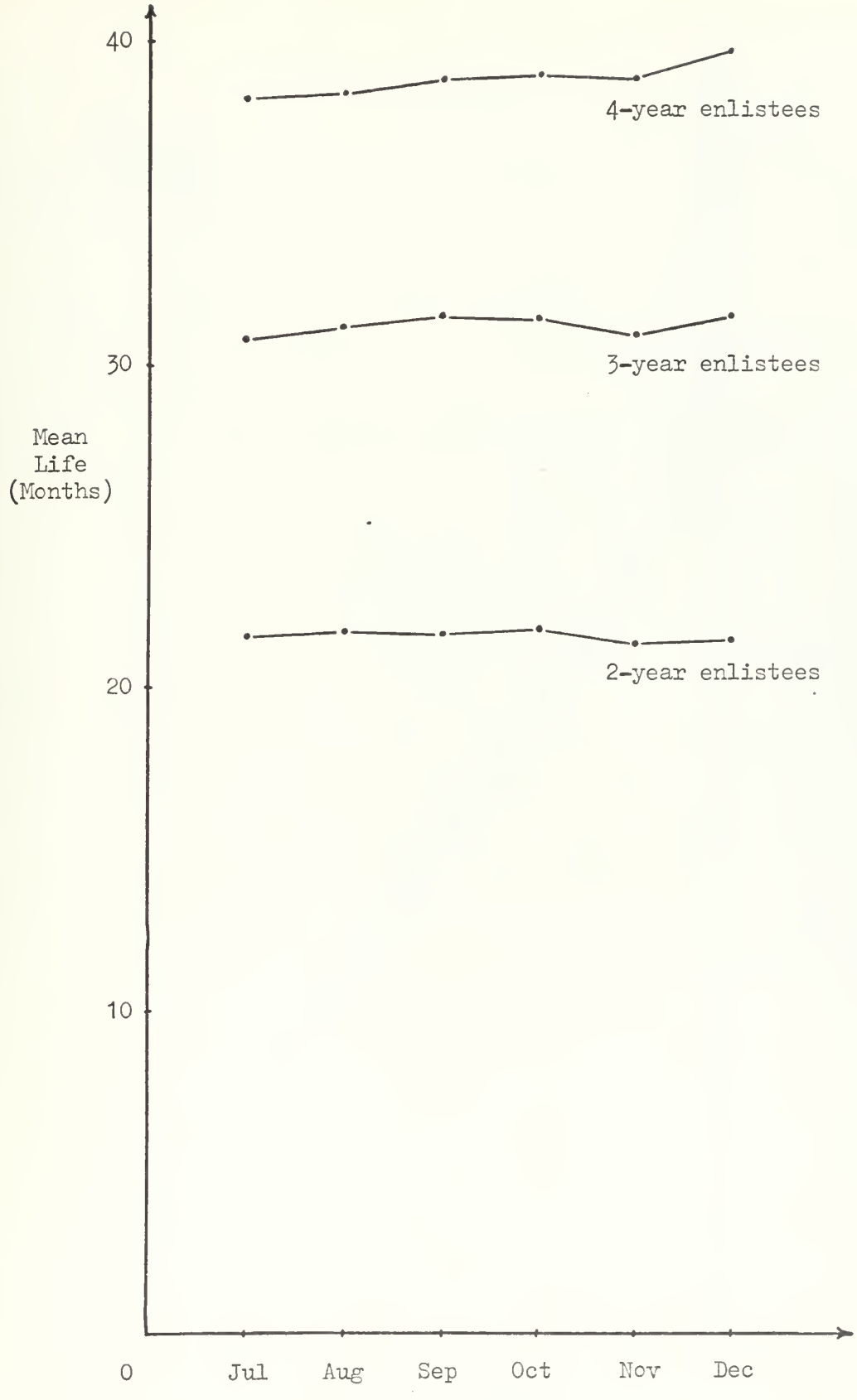

Figure 9: EOAS Mean Lifetimes

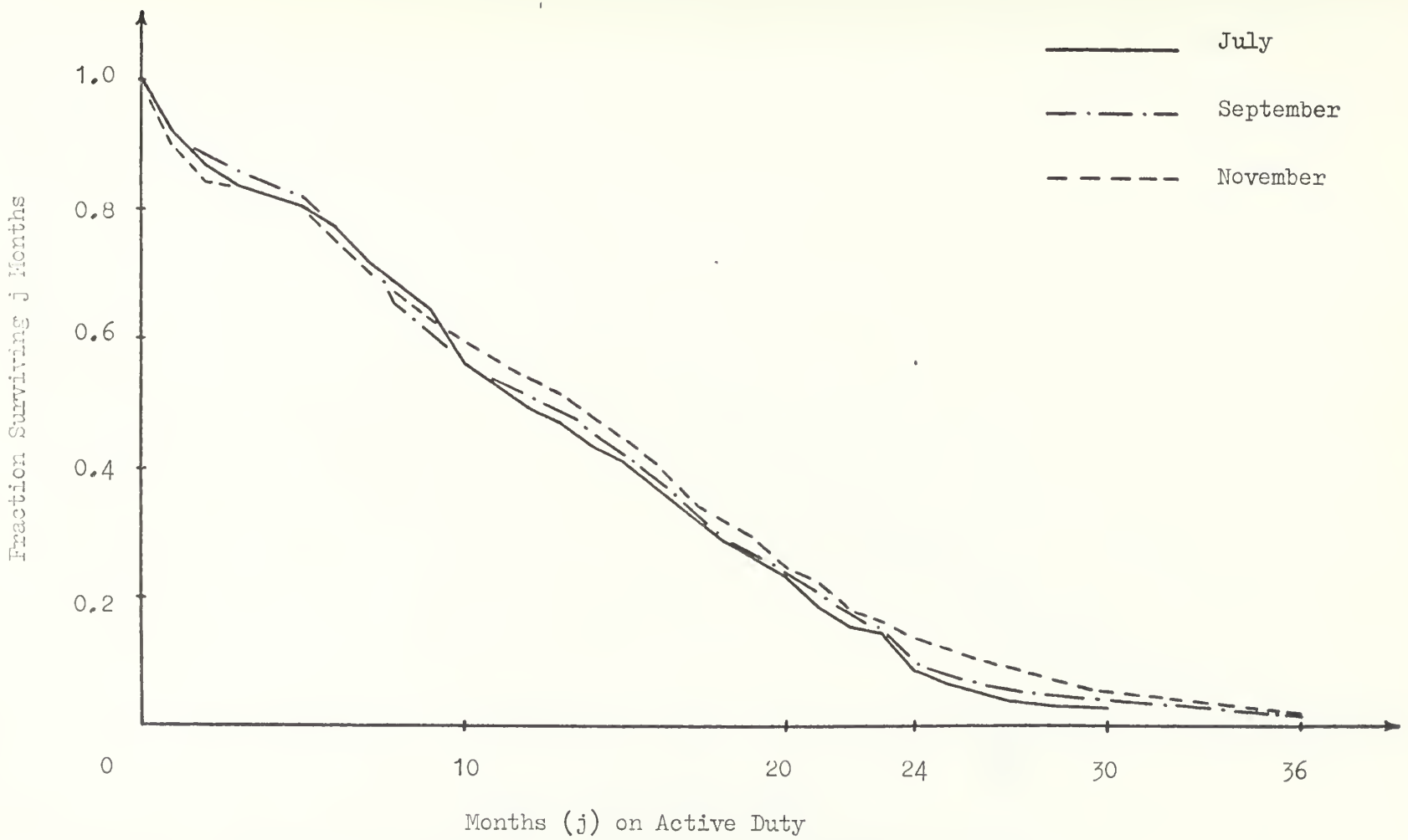

Figure 10: Distributions for Two-year Attrition Cohorts
July, September, November 1967

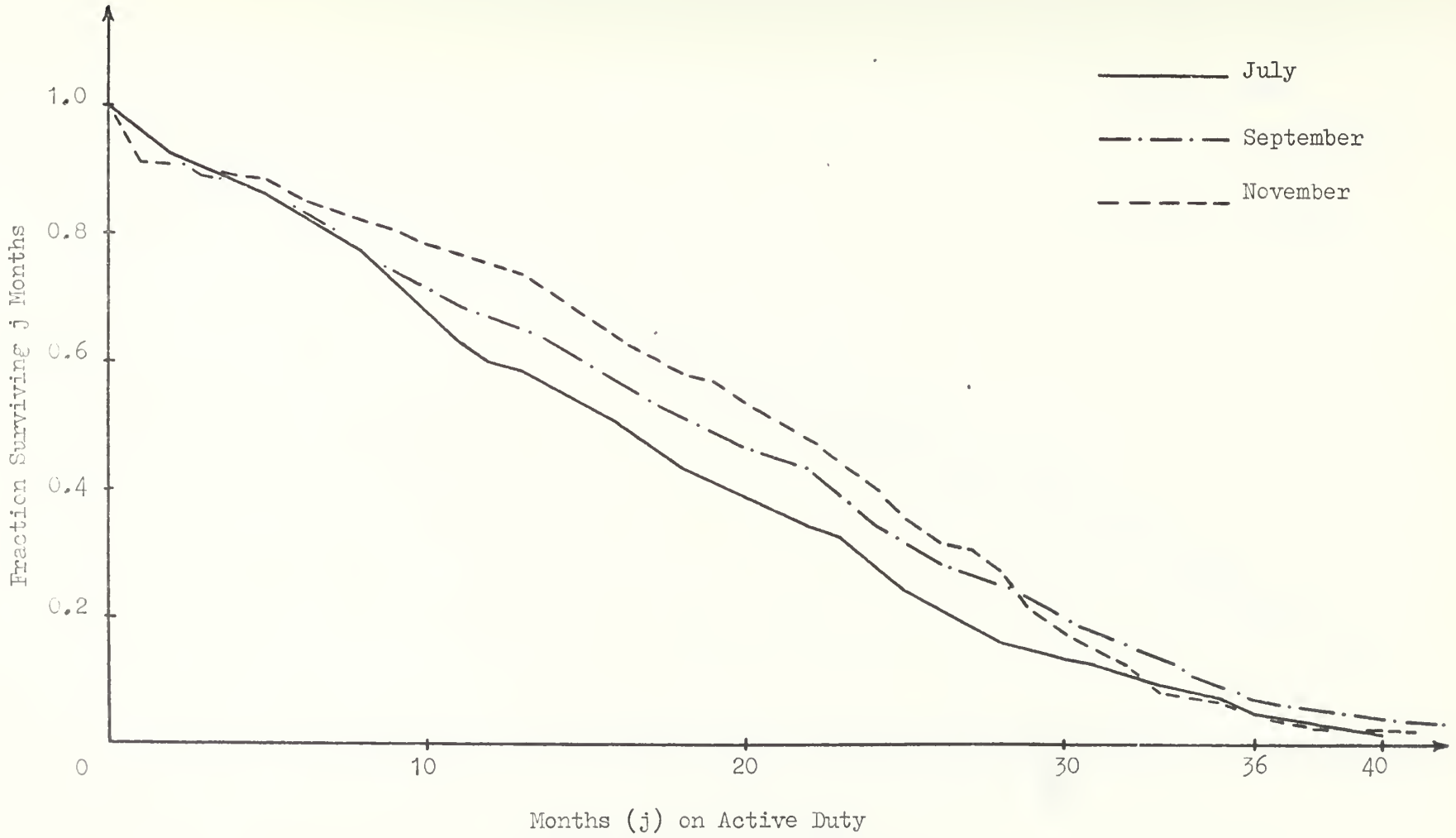

Figure 11: Distributions for Three-year Attrition Cohorts
July, September, November 1967

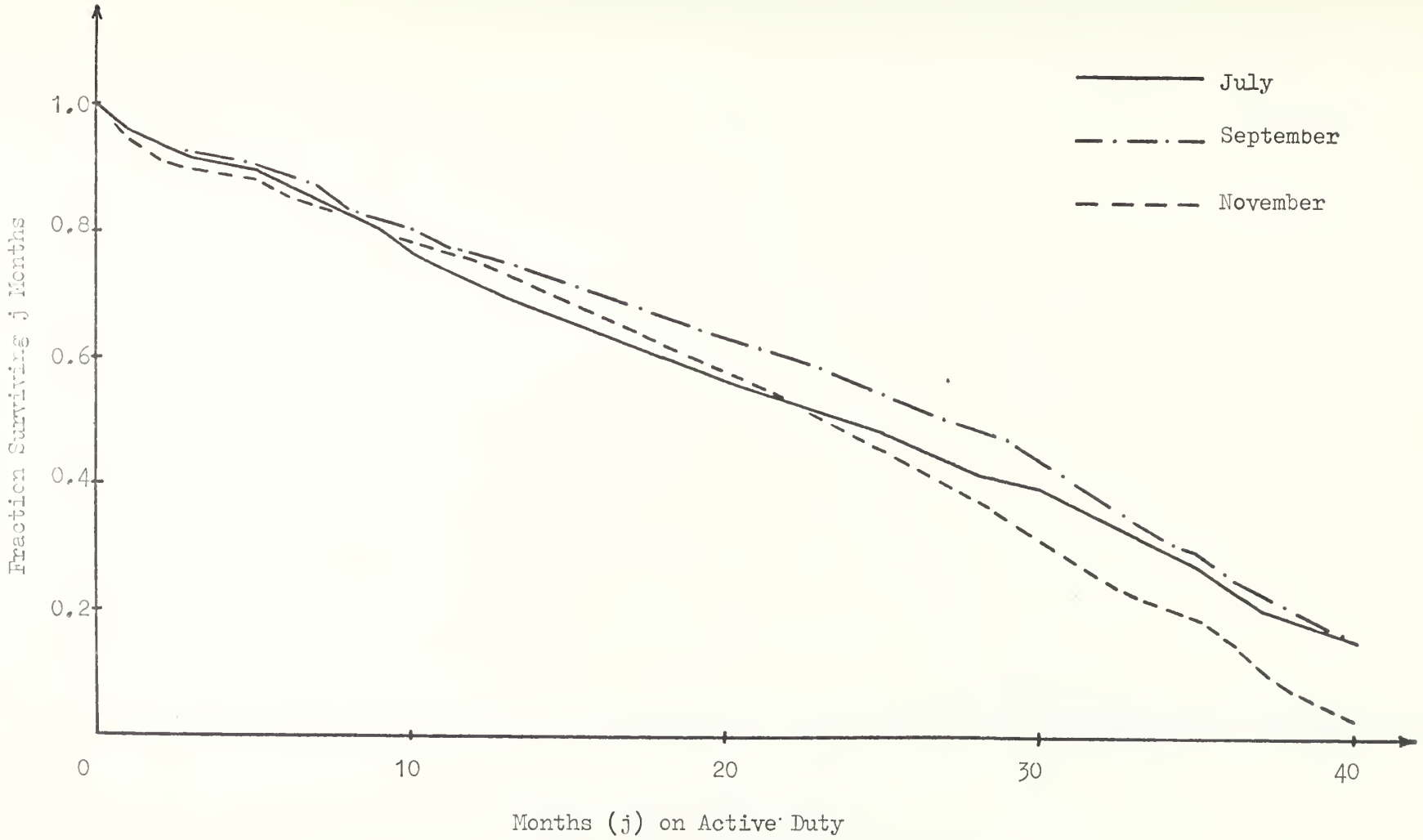

Figure 12: Distributions for Four-year Attrition Cohorts
July, September, November 1967

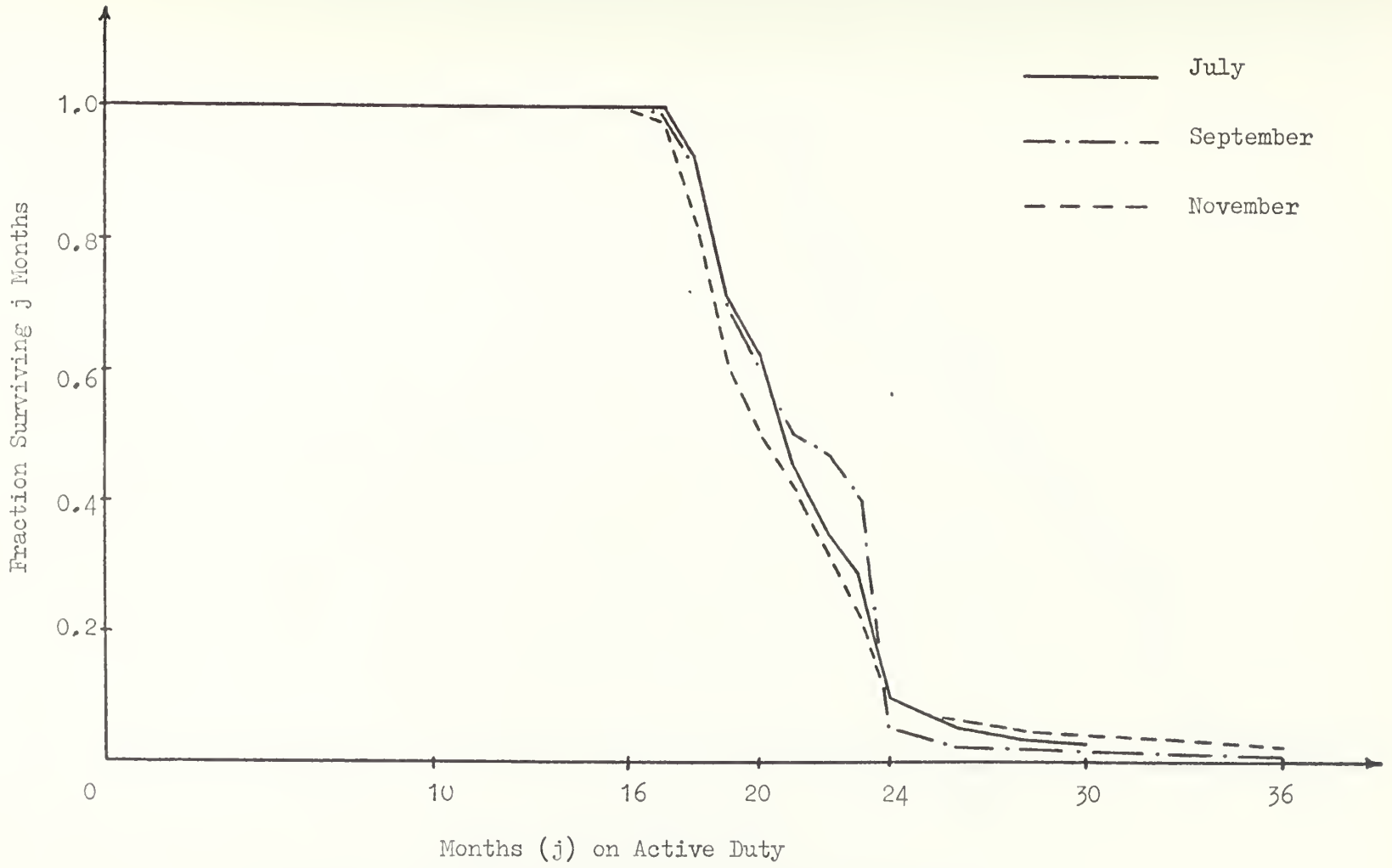

Figure 13: Distributions for Two-year EOAS Cohorts
July, September, November 1967

Figure 14: Distributions for Three-year EOAS Cohorts
July, September, November 1967

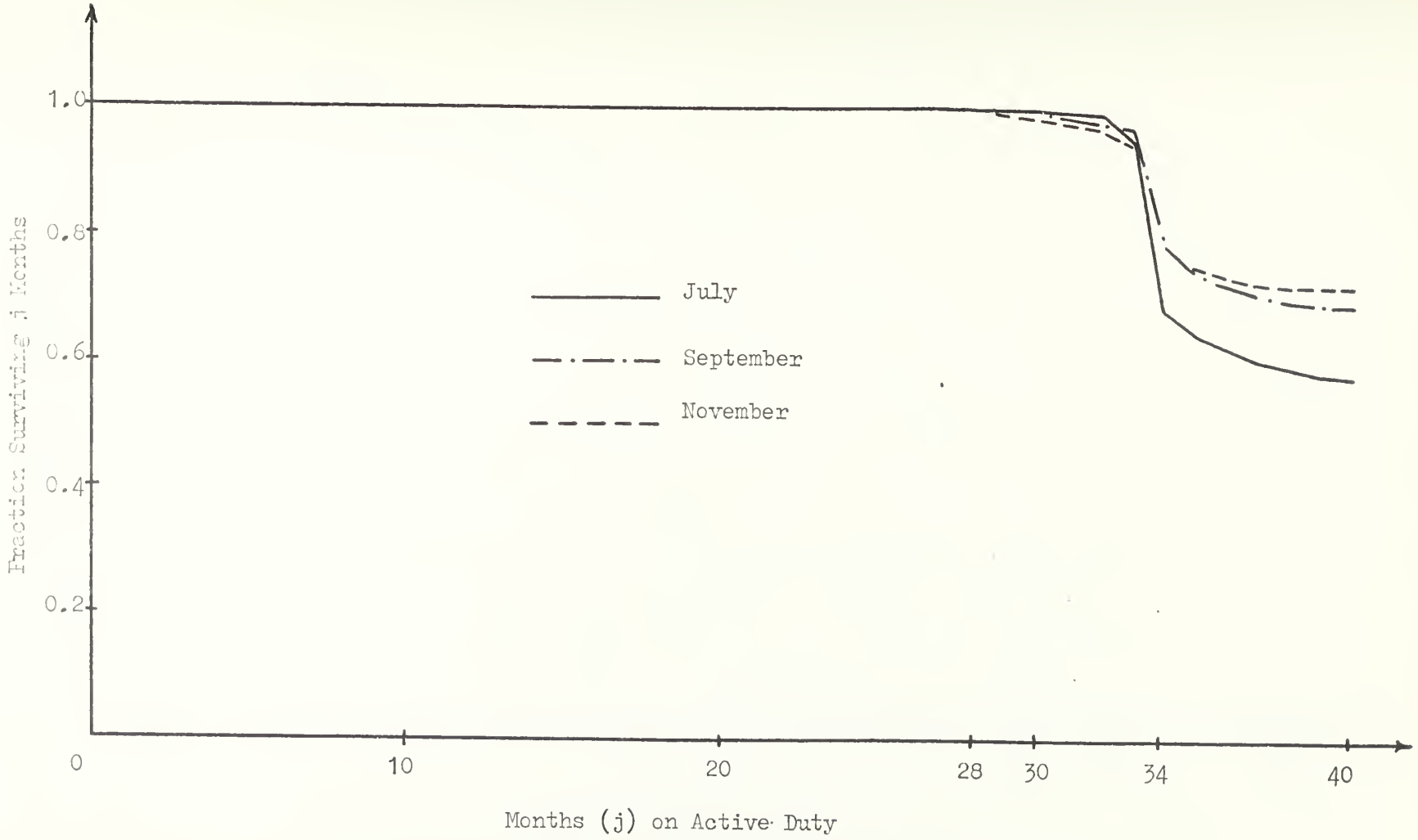

Figure 15: Distributions for Four-year EOAS Cohorts
July, September, November 1967

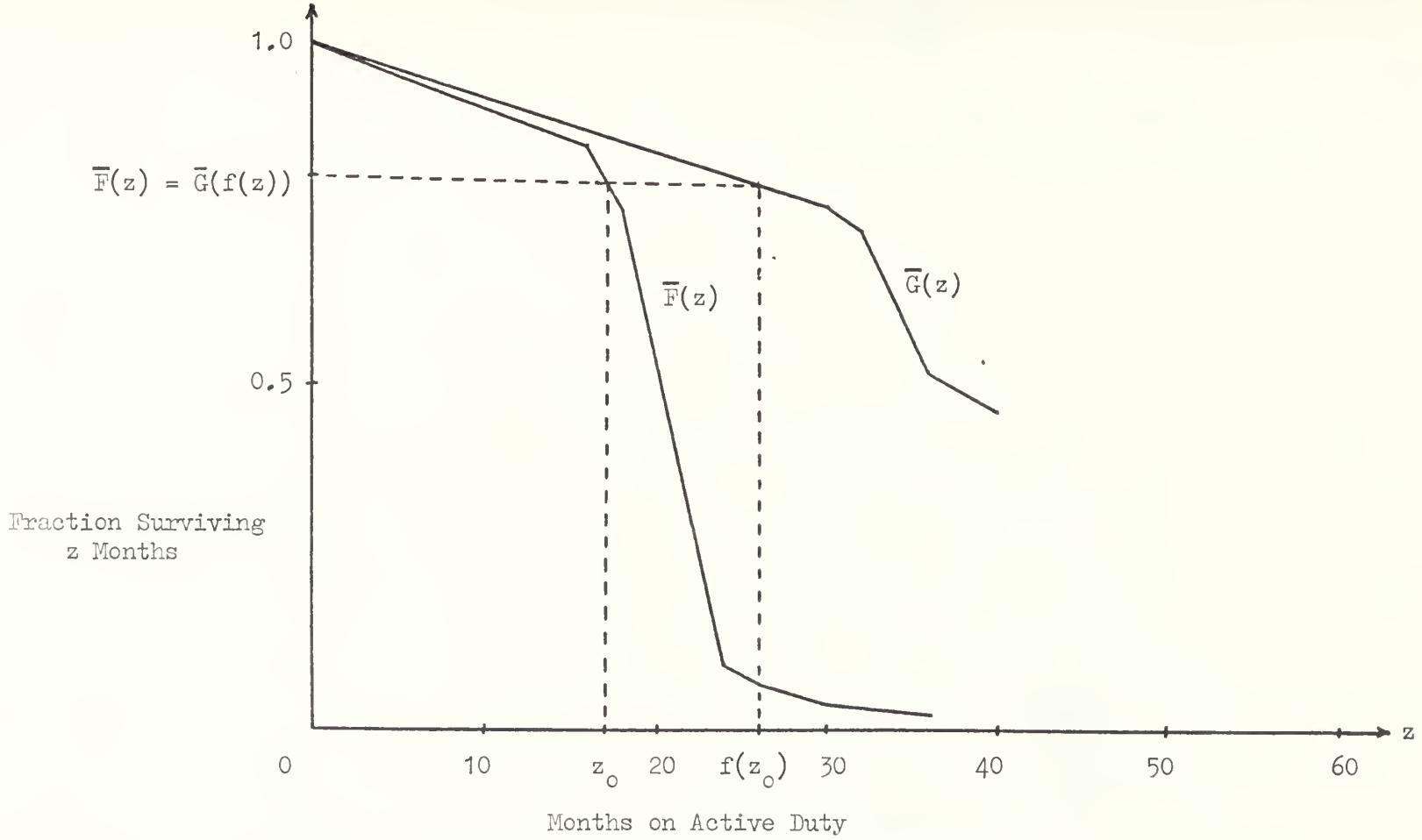

Figure 16: Relationship Between Distributions

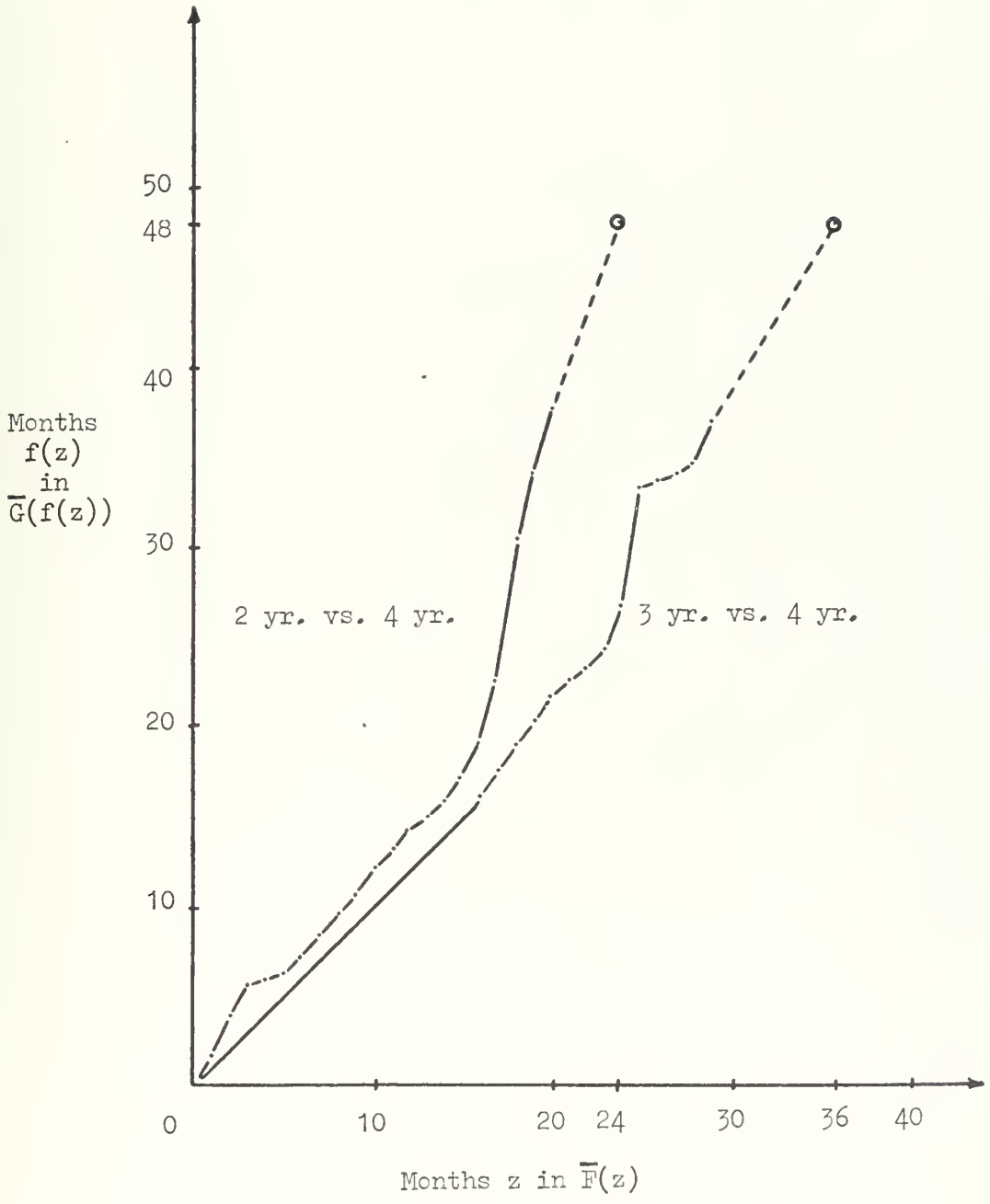

Figure 17: Functional Relationships

2 yr. vs. 4 year and 3 yr. vs. 4 yr.

Total Data Aggregate Distributions

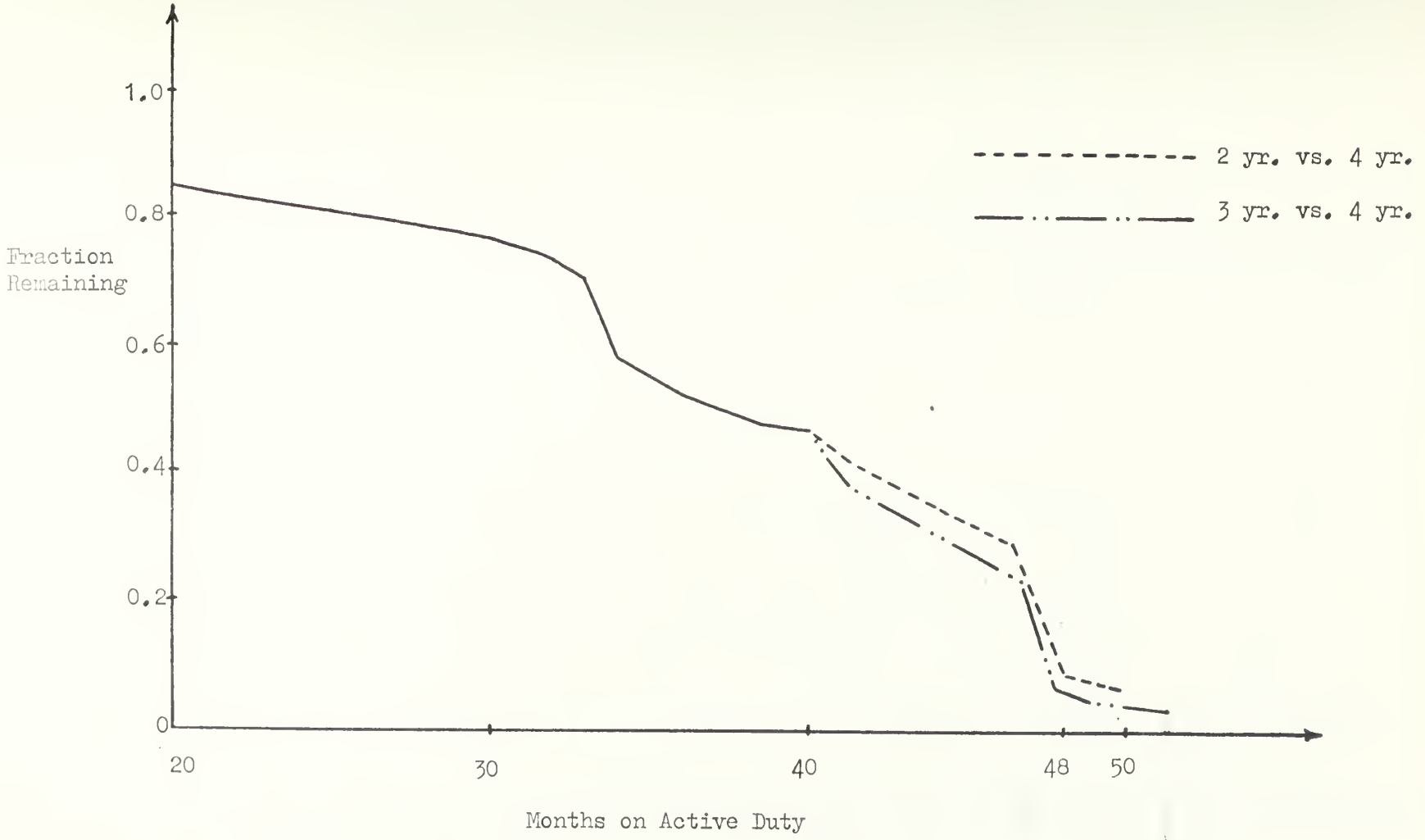

Figure 18: Aggregate Total Data Second-degree Polynomial Extrapolations

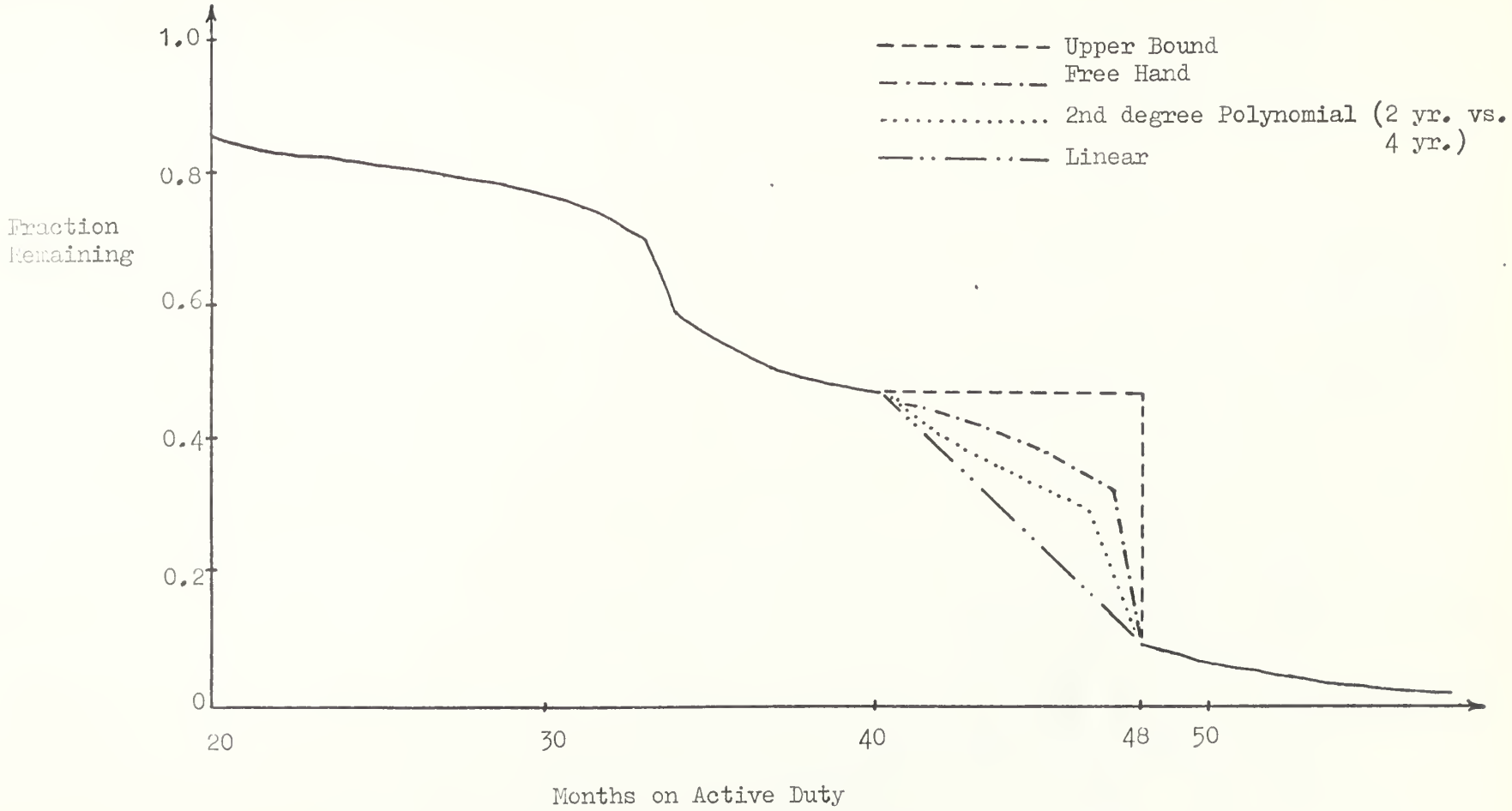

Figure 19: Aggregate Four-year Total Data Sensitivity Extrapolations

APPENDIX A

THE DATA BASE

The following data in the format described in Chapter II (Table I) provide the basis for the distributions plotted in this thesis. These data include two-year cohorts from July 1967 through June 1968 and three-year and four-year cohorts from July 1967 through December 1967. Also used as inputs to the model are the initial cohort strengths for all cohorts from January 1967 through December 1971. These values are listed.

Two - year Cohort Starting in July 1967

Initial Strength = 1725

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	36	0	0	0	0	36	1689
2	20	0	0	0	0	20	1669
3	13	0	0	0	0	13	1656
4	7	0	0	0	0	7	1649
5	8	0	1	0	0	9	1640
6	11	0	0	0	0	11	1629
7	25	0	0	1	0	26	1603
8	11	0	0	0	5	16	1587
9	12	0	0	0	2	14	1573
10	32	0	0	1	2	35	1538
11	13	0	0	0	0	13	1525
12	15	0	0	1	0	16	1509
13	9	0	1	0	0	10	1499
14	16	0	0	0	0	16	1483
15	10	0	0	0	0	10	1473
16	12	2	1	1	0	16	1457
17	17	2	3	1	0	23	1434
18	13	2	106	1	0	122	1312
19	13	0	279	1	0	293	1019
20	8	2	101	0	0	111	908
21	14	6	224	1	0	245	663
22	12	1	123	0	0	136	527
23	4	0	86	0	0	90	437
24	17	7	250	0	0	274	163
25	7	1	28	0	0	36	127
26	5	0	29	0	0	34	93
27	5	1	14	1	0	21	72
28	2	0	7	0	0	9	63
29	2	0	3	1	0	6	57
30	0	0	5	0	0	5	52
Total Losses	369	24	1261	10	9	1673	

Two - year Cohort Starting in August 1967

Initial Strength = 1822

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	35	0	0	0	0	35	1787
2	19	0	0	0	0	19	1768
3	10	0	0	0	0	10	1758
4	8	0	0	0	0	8	1750
5	5	0	0	1	0	6	1744
6	9	0	0	0	0	9	1735
7	12	0	0	0	1	13	1722
8	8	0	0	0	2	10	1712
9	30	0	0	1	8	39	1673
10	9	0	2	0	0	11	1662
11	18	0	1	0	0	19	1643
12	9	0	0	0	1	10	1633
13	14	0	0	0	0	14	1619
14	5	1	0	0	0	6	1613
15	12	2	0	0	0	14	1599
16	6	1	1	0	0	8	1591
17	17	0	9	0	0	26	1565
18	11	0	90	0	0	101	1464
19	15	2	260	0	0	277	1187
20	7	0	241	0	0	248	939
21	9	3	80	1	0	93	846
22	7	1	199	2	0	209	637
23	12	2	64	0	0	78	559
24	14	3	387	1	0	405	154
25	4	1	41	0	0	46	108
26	2	0	16	0	0	18	90
27	4	0	10	0	0	14	76
28	5	0	6	0	0	11	65
29	2	0	2	0	0	4	61
30	0	0	3	0	0	3	58
31	3	0	2	0	0	5	53
32	2	1	1	0	0	4	49
33	3	0	2	0	0	5	44
34	4	0	2	0	0	6	38
35	4	0	0	0	0	4	34
36	0	0	2	0	0	2	32
Total Losses	334	17	1421	6	12	1790	

Two - year Cohort Starting in September 1967

Initial Strength = 1848

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	32	0	0	0	0	32	1816
2	10	0	0	0	0	10	1806
3	7	0	0	0	0	7	1799
4	8	0	0	0	0	8	1791
5	5	0	0	1	0	6	1785
6	15	0	0	2	0	17	1768
7	11	0	0	0	5	16	1752
8	19	0	1	0	10	30	1722
9	13	0	0	0	0	13	1709
10	15	0	1	0	0	16	1693
11	9	0	0	0	3	12	1681
12	6	0	0	1	0	7	1674
13	8	0	0	0	1	9	1665
14	13	0	0	0	0	13	1652
15	9	1	0	0	0	10	1642
16	15	0	5	0	0	20	1622
17	13	1	13	0	0	27	1595
18	16	1	117	0	0	134	1461
19	7	2	328	0	0	337	1124
20	9	1	149	0	0	159	965
21	8	3	128	0	0	139	826
22	8	3	43	0	0	54	772
23	7	2	102	0	0	111	661
24	13	6	529	0	0	548	113
25	7	0	25	0	0	32	81
26	4	0	16	0	0	20	61
27	4	0	3	0	0	7	54
28	2	0	1	0	0	3	51
29	1	0	4	0	0	5	46
30	2	0	3	0	0	5	41
31	0	0	1	0	0	1	40
32	1	0	1	0	0	2	38
33	2	0	0	0	0	2	36
34	2	0	2	0	0	4	32
35	1	0	1	0	0	2	30
36	2	0	4	0	0	6	24
Total Losses	304	20	1477	4	19	1824	

Two - year Cohort Starting in October 1967

Initial Strength = 2034

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	38	0	0	0	0	38	1996
2	35	0	0	1	0	36	1960
3	15	0	0	0	0	15	1945
4	10	0	0	0	0	10	1935
5	5	0	0	0	0	5	1930
6	10	0	0	1	0	11	1919
7	32	0	0	0	3	35	1884
8	20	0	0	0	0	20	1864
9	10	0	0	0	0	10	1854
10	22	0	0	0	8	30	1824
11	10	0	0	0	0	10	1814
12	13	0	0	1	1	15	1799
13	10	1	0	0	0	11	1788
14	10	1	0	1	0	12	1776
15	14	0	0	1	0	15	1761
16	12	1	5	1	1	20	1741
17	19	2	10	0	0	31	1710
18	14	2	73	1	1	91	1619
19	18	0	376	0	0	394	1225
20	5	1	205	0	0	211	1014
21	9	2	72	1	0	84	930
22	17	6	110	2	0	135	795
23	16	1	137	0	0	154	641
24	17	5	432	0	0	454	187
25	13	0	33	0	0	46	141
26	7	0	17	0	0	24	117
27	3	0	18	1	0	22	95
28	3	0	3	1	0	7	88
29	5	0	6	0	0	11	77
30	7	0	2	0	0	9	68
31	2	0	0	0	0	2	66
32	6	0	2	0	0	8	58
33	3	0	2	0	0	5	53
34	2	0	1	0	0	3	50
35	1	0	4	0	0	5	45
36	0	1	5	0	0	6	39
Total Losses	433	23	1513	12	14	1995	

Two - year Cohort Starting in November 1967

Initial Strength = 2174

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	58	0	0	0	0	58	2116
2	32	0	0	0	0	32	2084
3	6	0	0	0	0	6	2078
4	7	0	0	1	0	8	2070
5	6	0	0	0	0	6	2064
6	27	0	0	1	1	29	2035
7	30	0	1	0	0	31	2004
8	20	0	0	0	0	20	1984
9	19	0	0	0	5	24	1960
10	17	0	0	0	0	17	1943
11	14	0	0	0	4	18	1925
12	13	0	0	0	0	13	1912
13	13	0	0	1	1	15	1897
14	19	0	1	0	0	20	1877
15	19	0	10	2	0	31	1846
16	28	0	4	0	0	32	1814
17	24	3	24	2	0	53	1761
18	17	0	234	1	0	252	1509
19	14	1	361	0	0	376	1133
20	24	2	167	0	0	193	940
21	11	1	122	0	0	134	806
22	21	4	159	1	0	135	621
23	8	0	147	0	0	155	466
24	11	6	230	1	0	248	218
25	7	1	25	0	0	33	185
26	5	0	11	1	0	17	168
27	9	0	15	0	0	24	144
28	8	0	8	0	0	16	128
29	3	3	14	0	0	20	108
30	6	0	3	0	0	9	99
31	3	0	2	0	0	5	94
32	3	0	2	0	0	5	89
33	7	0	5	0	0	12	77
34	2	1	7	2	0	12	65
35	1	0	4	1	0	6	59
36	2	0	9	0	0	11	48
Total Losses	514	22	1565	14	11	2126	

Two - year Cohort Starting in December 1967

Initial Strength = 2367

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	43	0	0	0	0	43	2324
2	48	0	0	0	0	48	2276
3	22	0	0	0	0	22	2254
4	11	0	0	0	0	11	2243
5	13	0	0	0	0	13	2230
6	14	0	0	1	0	15	2215
7	12	0	0	1	0	13	2202
8	14	0	0	2	11	27	2175
9	24	0	0	2	0	26	2149
10	15	0	0	1	3	19	2130
11	15	0	0	0	1	16	2114
12	14	0	0	0	0	14	2100
13	16	1	1	0	0	18	2082
14	24	1	7	0	0	32	2050
15	26	0	4	0	0	30	2020
16	11	0	13	0	0	24	1996
17	25	1	87	2	0	115	1881
18	15	1	128	1	0	145	1736
19	13	4	325	0	0	342	1394
20	18	1	246	3	0	268	1126
21	16	3	205	0	0	224	902
22	16	5	92	1	0	114	788
23	10	0	105	3	0	118	670
24	15	6	398	1	0	420	250
25	11	0	30	0	0	41	209
26	6	0	18	2	0	26	183
27	12	0	14	0	0	26	157
28	2	1	13	1	0	17	140
29	8	0	9	1	0	18	122
30	5	0	7	0	0	12	110
31	6	0	2	1	0	9	101
32	2	0	7	0	0	9	92
33	1	0	11	0	0	12	80
34	5	0	3	0	0	8	72
35	4	0	7	0	0	11	61
36	2	0	10	0	0	12	49
Total Losses	514	24	1742	23	15	2318	

Two- year Cohort Starting in January 1968

Initial Strength = 4117

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	72	0	0	1	0	73	4044
2	57	0	0	1	0	58	3986
3	22	0	0	0	0	22	3964
4	14	0	0	0	0	14	3950
5	15	0	0	0	0	15	3935
6	31	0	1	0	0	32	3903
7	45	0	0	4	9	58	3845
8	33	0	1	1	0	35	3810
9	25	0	0	0	14	39	3771
10	26	0	0	0	4	30	3741
11	26	0	0	0	2	28	3713
12	21	1	0	2	0	24	3689
13	29	2	5	1	1	38	3651
14	46	0	2	1	0	49	3602
15	25	3	14	0	0	42	3560
16	43	2	107	0	0	152	3408
17	26	0	59	0	0	85	3323
18	42	5	305	1	0	353	2970
19	21	2	653	2	0	678	2292
20	30	1	438	2	0	471	1821
21	27	2	114	0	0	143	1678
22	19	6	98	1	0	124	1554
23	16	2	294	2	0	314	1240
24	24	11	742	2	0	779	461
25	21	0	71	3	0	95	366
26	13	0	28	1	1	43	323
27	10	0	25	0	0	35	288
28	18	0	13	0	0	31	257
29	11	0	7	1	0	19	238
30	8	0	14	0	0	22	216
Total Losses	816	37	2991	26	31	3901	

Two - year Cohort Starting in February 1968

Initial Strength = 3983

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	82	0	0	0	0	82	3901
2	50	0	0	0	0	50	3851
3	36	0	0	0	0	36	3815
4	14	0	0	0	0	14	3801
5	14	0	0	1	0	15	3786
6	31	0	0	0	1	32	3754
7	31	0	0	1	0	32	3722
8	25	0	0	3	8	36	3686
9	24	0	0	1	11	36	3650
10	20	0	0	0	6	26	3624
11	36	0	0	0	0	36	3588
12	33	0	1	0	4	38	3550
13	27	1	4	1	1	34	3516
14	36	3	18	1	1	59	3457
15	31	0	30	0	0	61	3396
16	24	1	89	1	0	115	3281
17	30	3	31	2	0	66	3215
18	31	1	237	2	0	271	2944
19	31	2	873	1	0	907	2037
20	36	1	185	1	0	223	1814
21	25	2	154	1	1	183	1631
22	27	5	122	0	0	154	1477
23	17	4	232	1	0	254	1223
24	35	7	767	1	0	810	413
25	17	0	89	0	0	106	307
26	15	3	33	0	0	51	256
27	12	1	16	0	0	29	227
28	10	1	19	0	0	30	197
29	6	3	6	2	0	17	180
30	10	0	8	0	0	18	162
Total Losses	816	38	2914	20	33	3821	

Two - year Cohort Starting in March 1968

Initial Strength = 3519

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	73	0	0	0	0	73	3446
2	53	0	0	1	0	54	3392
3	27	0	0	0	0	27	3365
4	15	0	0	2	0	17	3348
5	19	0	0	1	0	20	3328
6	23	0	0	1	0	24	3304
7	19	0	1	3	3	26	3278
8	23	0	0	1	4	28	3250
9	26	0	1	1	3	31	3219
10	21	0	1	2	0	24	3195
11	24	0	0	1	3	28.	3167
12	26	1	0	2	4	33	3134
13	22	0	9	3	1	35	3099
14	37	1	14	2	0	54	3045
15	27	3	73	2	0	105	2940
16	26	1	22	1	0	50	2890
17	18	0	35	1	0	54	2836
18	21	1	354	2	0	378	2458
19	18	1	525	0	0	544	1914
20	19	0	220	0	0	239	1675
21	26	3	167	1	0	197	1478
22	19	0	185	2	0	206	1272
23	27	3	284	2	0	316	956
24	26	10	571	0	1	608	348
25	20	1	45	1	0	67	281
26	13	0	29	1	0	43	238
27	8	1	22	1	0	32	206
28	14	1	13	1	0	29	177
29	0	1	12	2	0	15	162
30	4	1	6	1	0	12	150
Total Losses	694	29	2589	38	19	3369	

Two - year Cohort Starting in April 1968

Initial Strength = 5834

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	141	0	0	0	0	141	5693
2	82	0	0	1	0	83	5610
3	53	0	0	2	0	55	5555
4	28	0	1	2	0	31	5524
5	19	0	0	3	0	22	5502
6	23	0	0	4	0	27	5475
7	34	0	0	3	0	37	5438
8	60	0	1	1	5	67	5371
9	35	0	0	0	0	35	5336
10	52	0	0	2	7	61	5275
11	53	0	0	0	9	62	5213
12	43	2	1	0	2	48	5165
13	53	0	24	1	0	78	5087
14	34	0	101	3	0	138	4949
15	45	2	18	4	0	69	4880
16	50	1	27	0	2	80	4800
17	48	1	56	1	0	106	4694
18	30	0	610	1	0	641	4053
19	33	0	610	0	0	643	3410
20	33	0	242	1	0	276	3134
21	40	1	323	1	0	365	2769
22	41	4	579	2	0	626	2143
23	41	4	432	0	0	477	1666
24	40	6	1229	1	0	1276	390
25	24	0	69	1	0	94	296
26	15	1	32	0	0	48	248
27	14	6	18	2	0	40	208
28	11	0	9	0	0	20	188
29	9	0	9	2	0	20	168
30	5	1	6	0	0	12	156
Total Losses	1189	29	4397	38	25	5678	

Two - year Cohort Starting in May 1968

Initial Strength = 5299

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	142	0	0	2	0	144	5155
2	117	0	0	0	0	117	5038
3	56	0	0	0	0	56	4982
4	27	0	0	0	0	27	4955
5	14	0	0	5	0	19	4936
6	27	0	0	0	0	27	4909
7	33	0	1	0	0	34	4875
8	33	0	0	1	0	34	4841
9	38	0	0	0	2	40	4801
10	36	0	0	3	2	41	4760
11	37	0	0	2	3	42	4718
12	40	2	1	2	2	47	4671
13	29	0	32	2	0	63	4608
14	34	1	29	2	0	66	4542
15	43	1	20	0	0	64	4478
16	42	1	36	4	0	83	4395
17	38	0	96	5	1	140	4255
18	25	0	609	2	0	636	3619
19	29	0	341	0	0	370	3249
20	34	0	176	0	0	210	3039
21	29	0	524	3	0	556	2483
22	39	6	349	1	0	395	2088
23	31	5	474	1	0	511	1577
24	30	5	1178	0	0	1213	364
25	27	0	65	0	0	92	272
26	19	2	30	2	0	53	219
27	11	1	25	2	0	39	180
28	4	0	18	0	0	22	158
29	9	0	5	1	0	15	143
30	6	0	6	0	0	12	131
Total Losses	1079	24	4015	40	10	5168	

Two - year Cohort Starting in June 1968

Initial Strength = 4023

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	110	0	0	1	0	111	3912
2	74	0	0	1	0	75	3837
3	38	0	0	0	0	38	3799
4	16	0	0	1	0	17	3782
5	15	0	0	2	0	17	3765
6	12	0	1	2	0	15	3750
7	21	0	0	1	0	22	3728
8	27	0	0	0	1	28	3700
9	28	0	0	1	3	32	3668
10	20	0	0	2	1	23	3645
11	28	0	0	0	0	28	3617
12	20	0	0	1	2	23	3594
13	33	1	48	1	0	83	3511
14	41	0	24	2	1	68	3443
15	26	4	27	0	0	57	3386
16	32	0	52	2	0	86	3300
17	19	1	80	0	0	100	3200
18	29	0	517	1	1	548	2652
19	30	0	237	0	0	267	2385
20	35	0	448	1	0	484	1901
21	26	2	236	2	0	266	1635
22	31	6	278	2	0	317	1318
23	22	5	114	3	0	144	1174
24	20	7	850	1	0	878	296
25	10	2	43	1	0	56	240
26	17	1	16	1	0	35	205
27	7	2	15	2	0	26	179
28	8	0	8	0	0	16	163
29	6	0	14	0	0	20	143
30	1	1	3	0	0	5	138
Total Losses	802	32	3011	31	9	3885	

Three - year Cohort Starting in July 1967

Initial Strength = 1752

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	26	0	0	0	0	26	1726
2	14	0	0	0	0	14	1712
3	12	0	0	0	0	12	1700
4	10	0	0	1	0	11	1689
5	8	0	0	2	0	10	1679
6	12	0	0	3	0	15	1664
7	16	0	0	1	0	17	1647
8	13	0	0	0	1	14	1633
9	15	0	0	0	6	21	1612
10	24	0	0	1	4	29	1583
11	21	0	0	1	0	22	1561
12	15	0	0	1	0	16	1545
13	8	0	0	0	0	8	1537
14	13	0	0	0	0	13	1524
15	11	0	0	0	0	11	1513
16	18	0	0	1	0	19	1494
17	14	0	0	1	0	15	1479
18	20	0	0	0	0	20	1459
19	10	0	2	0	0	12	1447
20	10	0	1	1	0	12	1435
21	11	0	0	0	0	11	1424
22	13	0	1	1	0	15	1409
23	5	0	0	1	0	6	1403
24	18	6	6	0	0	30	1373
25	12	6	342	2	0	362	1011
26	10	2	51	0	0	63	948
27	12	3	17	1	0	33	915
28	9	3	7	2	0	21	894
29	3	2	14	1	1	21	873
30	4	0	10	0	0	14	859
31	6	0	235	0	0	241	618
32	6	1	56	1	0	64	554
33	8	2	97	0	0	107	447
34	2	1	38	0	0	41	406
35	7	0	49	1	0	57	349
36	7	6	250	1	0	264	85
37	5	0	24	0	0	29	56
38	1	0	4	0	0	5	51
39	4	0	7	0	0	11	40
40	2	0	2	0	0	4	36
Total Losses	435	32	1213	24	12	1716	

Three - year Cohort Starting in August 1967

Initial Strength = 2134

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	32	0	0	0	0	32	2102
2	20	0	0	1	0	21	2081
3	8	0	0	0	0	8	2073
4	11	0	0	0	0	11	2062
5	6	0	0	1	0	7	2055
6	7	0	0	1	0	8	2047
7	11	0	0	1	0	12	2035
8	17	0	0	0	2	19	2016
9	29	0	1	0	4	34	1982
10	16	0	0	1	0	17	1965
11	20	0	0	1	0	21	1944
12	22	0	0	0	0	22	1922
13	20	0	0	0	0	20	1902
14	17	0	1	0	0	18	1884
15	22	0	0	1	0	23	1861
16	13	0	0	0	0	13	1848
17	17	0	0	0	0	17	1831
18	17	0	1	0	0	18	1813
19	19	0	1	0	0	20	1793
20	26	0	0	2	0	28	1765
21	15	0	1	1	0	17	1748
22	8	0	1	0	0	9	1739
23	19	0	1	0	0	20	1719
24	19	6	25	3	0	53	1666
25	15	6	304	2	0	327	1339
26	11	2	57	2	0	72	1267
27	6	4	20	0	0	30	1237
28	8	5	11	2	0	26	1211
29	8	2	16	0	0	26	1185
30	13	2	203	1	0	219	966
31	8	3	159	2	0	172	794
32	10	0	123	1	0	134	660
33	9	0	46	0	0	55	605
34	10	1	92	1	0	104	501
35	3	2	69	0	0	74	427
36	12	8	298	0	0	318	109
37	6	1	19	0	0	26	83
38	5	0	11	2	0	18	65
39	4	0	4	0	0	8	57
40	2	0	2	0	0	4	53
41	1	0	1	0	0	2	51
42	2	0	0	0	0	2	49
43	1	0	0	0	0	1	48
44	2	0	0	1	0	3	45
Total Losses	547	42	1467	27	6	2089	

Three - year Cohort Starting in September 1967

Initial Strength = 2501

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	32	0	0	0	0	32	2469
2	26	0	0	0	0	26	2443
3	20	0	0	0	0	20	2423
4	7	0	0	1	0	8	2415
5	8	0	0	4	0	12	2403
6	13	0	0	2	1	16	2387
7	18	0	0	0	1	19	2368
8	25	0	0	0	9	34	2334
9	11	0	0	0	0	11	2323
10	17	0	0	0	0	17	2306
11	22	0	1	1	1	25	2281
12	9	0	0	0	0	9	2272
13	9	0	0	0	4	13	2259
14	15	0	0	0	0	15	2244
15	20	0	0	0	1	21	2223
16	21	0	0	1	0	22	2201
17	18	0	0	2	1	21	2180
18	17	0	0	1	0	18	2162
19	13	0	0	2	0	15	2147
20	16	0	0	0	0	16	2131
21	9	0	3	3	0	15	2116
22	9	1	1	0	0	11	2105
23	28	0	3	0	1	32	2073
24	19	10	14	2	0	45	2028
25	11	8	307	1	0	327	1701
26	13	7	66	1	0	87	1614
27	10	2	31	1	0	44	1570
28	10	1	28	1	0	40	1530
29	12	4	195	2	0	213	1317
30	11	7	183	1	0	202	1115
31	12	2	135	2	0	151	964
32	12	2	45	0	0	59	905
33	8	2	87	0	0	97	808
34	16	4	56	0	0	76	732
35	8	4	95	0	0	107	625
36	11	4	426	1	0	442	183
37	5	1	24	0	0	30	153
38	4	0	14	0	0	18	135
39	4	0	16	0	0	20	115
40	2	0	5	1	0	8	107
41	6	0	2	0	0	8	99
42	3	0	5	0	0	8	91
43	2	0	0	0	0	2	89
Total Losses	562	59	1742	30	19	2412	

Three - year Cohort Starting in October 1967

Initial Strength = 919

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	21	0	0	0	0	21	898
2	6	0	0	0	0	6	892
3	3	0	0	0	0	3	889
4	2	0	0	1	0	3	886
5	3	0	0	0	0	3	883
6	7	0	0	1	0	8	875
7	8	0	0	1	5	14	861
8	6	0	1	1	0	8	853
9	7	0	0	0	0	7	846
10	7	0	0	0	3	10	836
11	8	0	0	0	0	8	828
12	4	0	0	0	0	4	824
13	2	0	0	0	2	4	820
14	3	0	0	0	0	3	817
15	6	0	0	0	0	6	811
16	7	0	0	0	0	7	804
17	7	0	0	0	0	7	797
18	4	0	0	0	0	4	793
19	4	0	1	0	0	5	788
20	5	0	2	1	0	8	780
21	12	0	0	0	0	12	768
22	4	0	0	0	0	4	764
23	7	0	0	0	0	7	757
24	7	0	6	1	0	14	743
25	3	0	77	0	0	80	663
26	10	1	28	0	0	39	624
27	6	1	11	1	0	19	605
28	13	1	66	0	0	80	525
29	12	1	75	0	0	88	437
30	7	0	58	0	0	65	372
31	6	0	10	0	0	16	356
32	6	0	16	0	0	22	334
33	1	0	27	0	0	28	306
34	6	4	43	0	0	53	253
35	3	0	42	0	0	45	208
36	5	5	148	0	0	158	50
37	3	0	7	0	0	10	40
38	2	0	4	0	0	6	34
39	1	0	1	1	0	3	31
40	1	0	0	0	0	1	30
41	1	0	0	1	0	2	28
Total Losses	236	13	623	9	10	891	

Three - year Cohort Starting in November 1967

Initial Strength = 776

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	23	0	0	0	0	23	753
2	1	0	0	0	0	1	752
3	2	0	0	0	0	2	750
4	2	0	0	1	0	3	747
5	0	0	0	1	0	1	746
6	7	0	0	1	0	8	738
7	2	0	0	2	0	4	734
8	4	0	0	0	0	4	730
9	4	0	0	0	0	4	726
10	5	0	0	1	0	6	720
11	3	0	0	0	0	3	717
12	4	0	0	0	0	4	713
13	3	0	0	0	1	4	709
14	9	0	0	0	0	9	700
15	9	0	0	0	0	9	691
16	8	0	0	0	0	8	683
17	6	0	0	0	0	6	677
18	8	0	0	0	0	8	669
19	3	0	0	0	0	3	666
20	8	0	1	1	0	10	656
21	5	0	0	1	0	6	650
22	7	0	0	1	0	8	642
23	10	0	3	0	0	13	629
24	5	2	10	0	0	17	612
25	11	4	116	0	0	131	481
26	8	0	12	0	0	20	461
27	3	0	31	0	0	34	427
28	6	3	29	0	0	38	389
29	13	2	51	1	0	67	322
30	8	0	5	1	0	14	308
31	5	1	7	0	0	13	295
32	5	2	8	0	0	15	280
33	8	2	30	0	0	40	240
34	3	0	39	0	0	42	198
35	2	2	51	0	0	55	143
36	2	2	87	0	0	91	52
37	1	0	16	0	0	17	35
38	3	0	4	0	0	7	28
39	0	0	4	0	0	4	24
40	1	0	1	0	0	2	22
41	0	0	1	0	0	1	21
Total Losses	217	20	506	11	1	755	

Three - year Cohort Starting in December 1967

Initial Strength = 767

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	9	0	1	0	0	10	757
2	11	0	0	0	0	11	746
3	1	0	0	0	0	1	745
4	3	0	0	1	0	4	741
5	2	0	0	0	0	2	739
6	3	0	0	0	0	3	736
7	1	0	0	0	0	1	735
8	6	0	0	1	2	9	726
9	5	0	0	0	0	5	721
10	2	0	0	0	2	4	717
11	8	0	0	0	0	8	709
12	6	0	0	0	0	6	703
13	2	0	0	0	0	2	701
14	6	0	0	0	0	6	695
15	6	0	0	0	0	6	689
16	9	0	0	0	0	9	680
17	8	0	0	0	0	8	672
18	6	0	0	1	0	7	665
19	8	0	0	1	0	9	656
20	9	0	0	0	0	9	647
21	7	0	0	0	0	7	640
22	4	0	1	0	0	5	635
23	2	0	0	1	0	3	632
24	8	1	3	0	0	12	620
25	5	1	56	2	0	64	556
26	8	1	40	0	0	49	507
27	8	2	25	0	0	35	472
28	8	1	57	1	0	67	405
29	10	0	50	2	0	62	343
30	3	0	15	0	0	18	325
31	4	1	6	0	0	11	314
32	4	0	17	0	0	21	293
33	1	2	27	0	0	30	263
34	4	0	15	1	0	20	243
35	5	1	37	0	0	43	200
36	5	2	122	0	0	129	71
37	3	0	9	0	0	12	59
38	0	0	2	0	0	2	57
39	2	0	4	1	0	7	50
40	1	0	0	0	0	1	49
Total Losses	203	12	487	12	4	718	

Four - year Cohort Starting in July 1967

Initial Strength = 5378

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	86	0	0	1	0	87	5291
2	48	0	0	0	0	48	5243
3	38	0	0	0	0	38	5205
4	19	0	0	1	0	20	5185
5	20	0	1	0	0	21	5164
6	41	0	0	2	1	44	5120
7	43	0	0	1	3	47	5073
8	40	0	0	1	6	47	5026
9	42	0	0	1	3	46	4980
10	79	0	0	1	5	85	4895
11	50	0	0	3	0	53	4842
12	37	0	0	0	0	37	4805
13	52	0	0	2	1	55	4750
14	35	0	0	0	0	35	4715
15	23	0	0	1	4	28	4687
16	39	0	0	2	0	41	4646
17	39	0	1	2	0	42	4604
18	35	0	1	1	0	37	4567
19	43	0	0	1	0	44	4523
20	35	0	0	2	0	37	4486
21	31	1	0	2	1	35	4451
22	35	0	2	0	0	37	4414
23	29	0	0	3	0	32	4382
24	32	0	1	1	0	34	4348
25	26	0	6	2	0	34	4314
26	45	0	3	2	0	50	4264
27	44	0	1	3	0	48	4216
28	38	0	0	1	0	39	4177
29	24	0	0	1	0	25	4152
30	21	0	0	2	0	23	4129
31	42	0	2	2	0	46	4083
32	51	0	18	0	0	69	4014
33	54	0	133	6	0	193	3821
34	41	0	890	3	0	934	2887
35	47	0	128	4	0	179	2708
36	28	38	70	2	0	138	2570
37	25	39	68	3	0	135	2435
38	13	23	36	3	0	75	2360
39	27	8	30	1	0	66	2294
40	18	11	17	2	0	48	2246
41	25	11	101	2	0	139	2107
42	16	7	3	1	0	27	2080
43	13	7	1	2	0	23	2057
44	11	2	13	1	0	27	2030
Total Losses	1580	147	1526	71	24	3348	

Four - year Cohort Starting in August 1967

Initial Strength = 4198

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	79	0	0	0	0	79	4119
2	51	0	0	0	0	51	4068
3	23	0	0	1	0	24	4044
4	19	0	0	3	0	22	4022
5	12	0	0	1	0	13	4009
6	30	0	0	2	0	32	3977
7	36	0	0	2	1	39	3938
8	26	0	0	1	0	27	3911
9	50	0	0	0	7	57	3854
10	22	0	0	0	0	22	3832
11	26	0	0	3	0	29	3803
12	33	0	0	1	2	36	3767
13	27	0	0	2	0	29	3738
14	28	0	0	1	0	29	3709
15	27	0	0	0	1	28	3681
16	31	0	0	3	1	35	3646
17	33	0	0	1	0	34	3612
18	30	0	0	0	0	30	3582
19	23	0	0	0	0	23	3559
20	20	0	2	0	0	22	3537
21	29	1	1	4	0	35	3502
22	23	0	1	1	0	25	3477
23	32	1	0	4	0	37	3440
24	32	0	0	1	0	33	3407
25	31	0	0	2	0	33	3374
26	24	0	1	1	0	26	3348
27	20	0	0	3	0	23	3325
28	30	0	1	3	0	34	3291
29	28	0	2	2	0	32	3259
30	26	0	1	2	0	29	3230
31	45	0	10	2	0	57	3173
32	36	0	25	3	0	64	3109
33	35	0	227	1	0	263	2846
34	30	0	443	2	0	475	2371
35	49	0	97	5	0	151	2220
36	25	28	70	2	0	125	2095
37	28	22	36	1	0	87	2008
38	16	12	23	2	0	53	1955
39	13	16	12	1	0	42	1913
40	29	12	20	1	0	62	1851
41	14	9	2	4	0	29	1822
42	15	9	0	1	0	25	1797
43	17	5	3	6	0	31	1766
44	7	3	8	3	0	21	1745
Total Losses	1260	118	985	78	12	2453	

Four - year Cohort Starting in September 1967

Initial Strength = 4045

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	68	0	0	0	0	68	3977
2	39	0	0	0	0	39	3938
3	16	0	0	0	0	16	3922
4	7	0	0	3	0	10	3912
5	12	0	0	0	0	12	3900
6	24	0	0	1	2	27	3873
7	24	0	0	2	1	27	3846
8	47	0	0	1	14	62	3784
9	20	0	0	1	0	21	3763
10	19	0	0	2	1	22	3741
11	28	0	1	1	9	39	3702
12	19	0	0	2	0	21	3681
13	20	0	0	3	2	25	3656
14	21	0	0	0	0	21	3635
15	24	0	0	1	2	27	3608
16	23	0	0	3	0	26	3582
17	22	0	0	3	0	25	3557
18	22	0	0	2	0	24	3533
19	34	0	0	1	0	35	3498
20	20	0	0	0	0	20	3478
21	16	0	2	1	1	20	3458
22	22	0	0	1	0	23	3435
23	27	0	1	2	0	30	3405
24	29	0	1	5	0	35	3370
25	32	0	0	3	2	37	3333
26	25	0	0	1	1	27	3306
27	22	0	1	4	1	28	3278
28	22	0	0	0	0	22	3256
29	24	0	2	2	1	29	3227
30	45	0	10	3	1	59	3168
31	48	0	21	2	0	71	3097
32	43	0	6	2	0	51	3046
33	45	0	37	4	0	86	2960
34	48	0	463	2	0	513	2447
35	26	0	107	3	0	136	2311
36	27	31	49	1	0	108	2203
37	23	15	32	2	0	72	2131
38	27	16	25	0	0	68	2063
39	21	17	20	1	0	59	2004
40	18	8	1	2	0	29	1975
41	13	10	1	1	0	25	1950
42	8	9	0	5	0	22	1928
43	12	8	0	2	0	22	1906
Total Losses	1132	114	780	75	38	2139	

Four - year Cohort Starting in October 1967

Initial Strength = 2554

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	43	0	0	0	0	43	2511
2	27	0	0	0	0	27	2484
3	16	0	0	0	0	16	2468
4	7	0	0	0	0	7	2461
5	6	0	0	0	0	6	2455
6	11	0	0	2	0	13	2442
7	28	0	0	1	7	36	2406
8	14	0	0	1	0	15	2391
9	12	0	0	1	1	14	2377
10	17	0	0	2	7	26	2351
11	14	0	1	1	0	16	2335
12	5	0	0	1	1	7	2328
13	16	0	0	0	2	18	2310
14	12	0	0	0	0	12	2298
15	17	0	0	0	1	18	2280
16	14	0	0	3	1	18	2262
17	16	0	0	1	0	17	2245
18	16	0	1	0	2	19	2226
19	19	0	1	1	0	21	2205
20	9	0	1	2	0	12	2193
21	21	0	1	4	0	26	2167
22	11	0	0	0	1	12	2155
23	22	0	1	2	0	25	2130
24	14	0	2	4	0	20	2110
25	16	0	0	0	0	16	2094
26	10	0	2	1	0	13	2081
27	20	0	0	0	0	20	2061
28	29	0	1	2	0	32	2029
29	29	0	9	2	0	40	1989
30	33	0	15	1	0	49	1940
31	19	0	8	3	0	30	1910
32	24	0	5	1	0	30	1880
33	28	1	18	4	0	51	1829
34	19	0	248	2	0	269	1560
35	12	0	65	5	0	82	1478
36	16	18	20	0	0	54	1424
37	15	12	17	2	0	46	1378
38	12	13	18	3	0	46	1332
39	13	8	1	1	0	23	1309
40	18	6	0	2	0	26	1283
41	9	5	0	3	0	17	1266
42	7	4	1	1	0	13	1253
Total Losses	716	67	436	59	23	1301	

Four - year Cohort Starting in November 1967

Initial Strength = 2517

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	50	0	0	0	0	50	2467
2	37	0	0	0	0	37	2430
3	13	0	0	0	0	13	2417
4	7	0	0	1	0	8	2409
5	5	0	0	1	0	6	2403
6	20	0	0	3	2	25	2378
7	16	0	0	0	0	16	2362
8	15	0	1	0	0	16	2346
9	14	0	0	0	11	25	2321
10	12	0	0	1	0	13	2308
11	15	0	0	0	0	15	2293
12	10	0	0	0	0	10	2283
13	23	0	0	1	2	26	2257
14	11	0	0	3	0	14	2243
15	25	0	0	0	1	26	2217
16	18	0	0	1	0	19	2198
17	19	0	0	0	0	19	2179
18	26	0	0	2	0	28	2151
19	16	0	0	0	0	16	2135
20	17	0	0	1	0	18	2117
21	23	0	0	2	0	25	2092
22	21	0	1	2	0	24	2068
23	19	0	0	3	1	23	2045
24	20	0	0	0	2	22	2023
25	25	0	0	1	0	26	1997
26	24	0	1	1	0	26	1971
27	22	0	0	1	0	23	1948
28	29	0	0	0	0	29	1919
29	32	0	11	1	0	44	1875
30	29	0	11	0	1	41	1834
31	28	0	11	4	0	43	1791
32	21	0	16	0	0	37	1754
33	26	0	41	2	0	69	1685
34	14	0	254	0	0	268	1417
35	18	1	50	1	0	70	1347
36	20	10	18	1	0	49	1298
37	23	18	19	5	0	65	1233
38	18	8	1	5	0	32	1201
39	13	9	0	1	0	23	1178
40	12	8	0	4	1	25	1153
41	3	2	0	1	0	6	1147
Total Losses	809	56	435	49	21	1370	

Four - year Cohort Starting in December 1967

Initial Strength = 2430

Month after start	Losses by Groups R1	R2	R3	R4	R5	Row Total	Number Remaining
1	47	0	0	0	0	47	2383
2	36	0	0	0	0	36	2347
3	11	0	0	0	0	11	2336
4	8	0	0	0	0	8	2328
5	10	0	1	0	0	11	2317
6	11	0	0	3	0	14	2303
7	5	0	0	5	0	10	2293
8	12	0	0	2	5	19	2274
9	9	0	0	3	0	12	2262
10	6	0	1	1	2	10	2252
11	12	0	0	5	1	18	2234
12	11	0	1	1	0	13	2221
13	15	0	0	2	0	17	2204
14	23	0	0	0	2	25	2179
15	13	1	0	1	0	15	2164
16	14	0	0	2	0	16	2148
17	13	0	0	1	0	14	2134
18	20	0	0	2	0	22	2112
19	11	0	0	0	0	11	2101
20	18	0	0	2	0	20	2081
21	19	0	0	0	0	19	2062
22	20	0	0	3	1	24	2038
23	13	0	0	1	0	14	2024
24	17	0	0	2	0	19	2005
25	16	0	0	6	0	22	1983
26	15	0	1	1	0	17	1966
27	26	0	1	0	1	28	1938
28	32	0	0	1	0	33	1905
29	34	0	5	3	0	42	1863
30	20	0	7	1	0	28	1835
31	32	0	13	7	0	52	1783
32	28	0	12	1	0	41	1742
33	15	0	13	2	0	30	1712
34	27	0	124	4	0	155	1557
35	15	0	30	1	0	46	1511
36	27	14	31	1	0	73	1438
37	15	20	1	1	0	37	1401
38	24	9	2	2	0	37	1364
39	15	3	0	2	0	20	1344
40	9	6	1	1	0	17	1327
Total Losses	724	53	244	70	12	1103	

COHORT		INITIAL COHORT STRENGTH		
Year	Month	Two-year	Three-year	Four-year
1967	Jan	24	1104	2801
	Feb	20	553	1914
	Mar	19	586	2926
	Apr	6	626	3431
	May	252	910	4855
	Jun	1107	1669	6617
	Jul	1725	1752	5378
	Aug	1822	2134	4198
	Sep	1848	2501	4045
	Oct	2034	919	2554
	Nov	2174	776	2517
	Dec	2367	767	2430
1968	Jan	4117	1203	3305
	Feb	3983	1087	2933
	Mar	3519	1102	2940
	Apr	5834	840	2234
	May	5299	1244	2515
	Jun	4023	1838	3505
	Jul	3287	1646	2633
	Aug	3484	1631	2483
	Sep	3493	1726	2354
	Oct	3987	1601	2397
	Nov	3490	1386	2055
	Dec	5516	944	1940
1969	Jan	4950	886	1825
	Feb	3862	664	1633
	Mar	3450	1062	1853
	Apr	2800	914	1567
	May	3077	902	1533
	Jun	3165	1515	2622
	Jul	4434	1688	2305
	Aug	4224	1488	1933
	Sep	4030	1370	2192
	Oct	4136	1456	2167
	Nov	3614	1427	2142
	Dec	3845	1211	1844

COHORT		INITIAL COHORT STRENGTH		
Year	Month	Two-year	Three-year	Four-year
1970	Jan	4091	1391	1935
	Feb	2358	1319	2313
	Mar	820	964	2204
	Apr	793	899	1969
	May	1020	854	1653
	Jun	1815	999	2656
	Jul	2026	1211	2533
	Aug	2601	1410	2671
	Sep	2455	1331	2596
	Oct	1539	832	1932
	Nov	1425	701	1744
	Dec	1415	583	1553
1971	Jan	2080	838	2072
	Feb	1728	725	1884
	Mar	1502	596	1592
	Apr	1360	587	1576
	May	1187	509	1412
	Jun	1575	781	2268
	Jul	2154	685	2417
	Aug	2286	594	2400
	Sep	2415	565	2167
	Oct	1981	460	1816
	Nov	1542	431	1575
	Dec	1294	426	1640

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13. ABSTRACT

Data from Marine Corps enlisted cohorts are analyzed to give insight into personnel flow through the enlisted Marine Corps system. In this paper, a cohort is a group of enlisted men who enlist in a given calendar month for a given length of obligated service. Stationarity assumptions between cohorts from different months are investigated. A major portion of the analysis is devoted to the extrapolation of the incomplete data on four-year enlistees based on the data from two-year and three-year enlistees. A prediction is made of enlisted strength for 1 January 1972 using the results of the analysis in a cohort prediction model. This is compared with the actual strength as of 1 January 1972. Refinements and associated models are suggested for further study.

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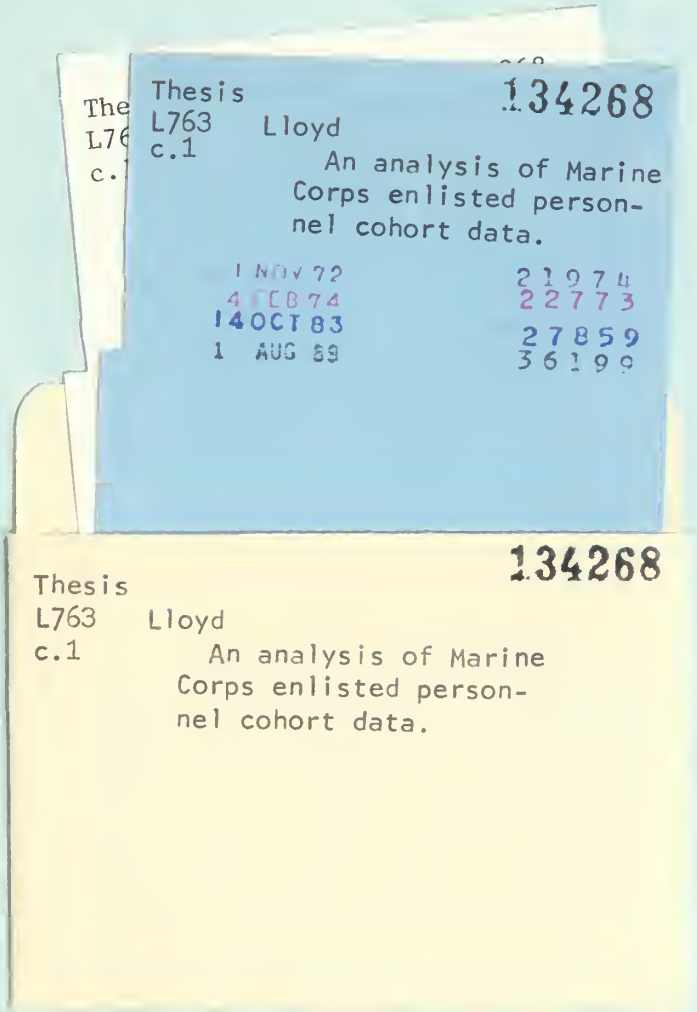

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